NASA LONG RANGE TECHNOLOGY GOALS

VOLUME II-B

TASK 2 REPORT

CONTRACT NASW - 3864

II. U.S. Industrial Sector Tech. Goals

III. Social, Health, & Security Tech. Goals

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This Volume contains the second part of the findings pertaining to the status of the U.S. industrial sector.

NASA Long Range Technology Goals

Volume II-B

Task 2 Report

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FOREWORD

This document is part of the Final Report performed under contract NASW-3864, titled "NASA Long Range Technology Goals."

The objectives of the effort were:

- To identify technologies whose development falls within NASA's capability and purview, and which have high potential for leapfrog advances in the national industrial posture in the 2005-2010 era.
- To define which of these technologies can also enable quantum jumps in the national space program.
- To assess mechanisms of interaction between NASA and industry constituencies for realizing the leapfrog technologies.

This Volume contains the second part of the findings pertaining to the status of the U.S. industrial sector.

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FOLLOWING IS A LIST OF THE ABBREVIATED GOVERNMENT AGENCIES CITED IN THIS VOLUME.

SOURCES:

U.S. DOC/BIE: U.S. Department of Commerce, Bureau of Industrial

U.S. DOL/BLS: U.S. Department of Labor, Bureau of Labor Statistics

U.S. DOC/BOC: U.S. Department of Commerce, Bureau of the Census

EOP/OMB: Executive Office of the President, Office of Management and Budget

EPA: Environmental Protection Agency

B.7 "CHEMICALS AND ALLIED PRODUCTS" (SIC 28)

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SOURCES: U.S. DOC/BOC:

Census of Manufactures, 1977

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U.S. DOC/BIE:

U.S. Industrial Outlook, 1984

U.S. DOC/OCA

U.S. DOL/BLS

EOP/OMB:

Standard Industrial Classification Manual, 1972

EPA:

1984 Cost of Clean Air and Water Report to Congress

OECO:

The Chemical Industry

U.S. International Trade Commission

National Academy of Sciences

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B.7 "CHEMICALS AND ALLIED PRODUCTS" (SIC 28)

The chemicals and allied products subsector, SIC 28, is the seventh largest manufacturing subsector, accounting for 4.3% of the manufacturing sector's portion of GDP. This subsector is characterized by:

- A high degree of fragmentation. Out of a total of approximately 12,000 establishments, 7,500 employed less than 20 persons (1977).

- A labor productivity of $45,829 per employee year or $23.87 per employee hour (1980, 1972 $), ranking this subsector third among the nation's 20 manufacturing subsectors. A compound annual labor productivity growth rate average of 1.9%/year from 1972 to 1980, ranks this subsector sixth. The labor productivity for the comparable Japanese subsector was $27,177 per employee year or $14.15 per employee hour (1980, 1972 $), ranking this subsector second among Japan's 20 manufacturing subsectors. The compound annual labor productivity growth rate for the Japanese subsector averaged 4.8%/year from 1972 to 1980, ranking this subsector thirteenth.

- An extremely high capital investment base relative to other subsectors within the manufacturing sector. Capital investment amounted to $50,366 in total assets per worker, ranking second in terms of (depreciated) fixed assets (1980, 1972 $). New yearly capital expenditures were $5,403 per employee (1980, 1972 $), ranking second in the manufacturing sector. Total capital productivity, measured as dollars of added value output per dollar of capital investment, was 0.67 (1981).

- A moderately aggressive R&D program. For the subsector as a whole, R&D expenditures amounted to $2.6 billion (1980, 1972 $), ranking this subsector fourth among the 20 manufacturing subsectors. R&D expenditures were equivalent to 6.2% of the value added by the subsector in 1980.

The chemicals and allied products subsector produces three general classes of products: 1) basic chemicals such as acids, alkalies, and olefins; 2) chemical intermediates, such as synthetic fibers, plastic resins, and rubber, which are used in further manufacturing; and 3) finished chemical products used for ultimate consumption such as drugs, cosmetics, soaps, and fertilizers. Table 7-1 shows the major products of each subdivision within the chemical and allied products subsector, with their contribution to the subsector's share of the manufacturing part of the GDP in 1980 ranked in descending order. Table 7-2 summarizes the principal economic features of these subdivisions.

A major industry which cuts across several of these subdivisions is the petrochemical industry. Figure 7-1 shows the major sources of raw material for the petrochemical industry.

Four subdivisions of the chemicals and allied products industry have been selected for an in-depth analysis in view of their contribution to the subsector (approximately 60% in 1980), and their potential for long-term technology development. These selected subdivisions are: Plastics Materials and Synthetics (SIC 282), Drugs (SIC 283), Industrial Organic Chemicals (SIC 286), and Agricultural Chemicals (SIC 287).

B.7.1 PLASTICS MATERIALS AND SYNTHETICS (SIC 282)

This subdivision includes establishments that are primarily engaged in the manufacture of plastics materials and synthetic resins, synthetic rubbers and cellulosic and manmade organic

TABLE 7-1

CLASSIFICATION OF MAJOR PRODUCTS OF THE CHEMICAL AND ALLIED PRODUCTS INDUSTRY (SIC 28) AND CONTRIBUTION TO SUBSECTOR IN 1980

SIC CODE	SUBDIVISION DESIGNATION AND TYPICAL PRODUCTS	% CONTRIBUTION
286	**INDUSTRIAL ORGANIC CHEMICALS** GUM AND WOOD CHEMICALS, CYCLIC CRUDES AND INTERMEDIATES, AND OTHER INDUSTRIAL CHEMICALS.	20.1
283	**DRUGS** BIOLOGICAL PRODUCTS, MEDICINALS AND BOTANICALS, AND PHARMACEUTICAL PREPARATIONS.	18.4
284	**SOAP, CLEANERS, AND TOILET GOODS** SOAP AND OTHER DETERGENTS, POLISHES AND SANITATION GOODS, SURFACE ACTIVE AGENTS, AND TOILET PREPARATIONS.	17.4
282	**PLASTICS MATERIALS AND SYNTHETICS** PLASTICS MATERIALS AND RESINS, SYNTHETIC RUBBER, CELLULOSIC MAN-MADE FIBERS, AND NONCELLULOSIC ORGANIC FIBERS.	13.3
281	**INDUSTRIAL INORGANIC CHEMICALS** ALKALIES AND CHLORINE, INDUSTRIAL GASES, INORGANIC PIGMENTS, AND OTHER INDUSTRIAL INORGANIC CHEMICALS.	11.9
287	**AGRICULTURAL CHEMICALS** NITROGENOUS FERTILIZERS, PHOSPHATE FERTILIZERS, MIXING FERTILIZERS, OTHER AGRICULTURAL CHEMICALS.	7.7
289	**MISCELLANEOUS CHEMICAL PRODUCTS** ADHESIVES AND SEALANTS, EXPLOSIVES, PRINTING INK, CARBON BLACK, AND OTHER CHEMICAL PREPARATIONS.	6.4
285	**PAINTS AND ALLIED PRODUCTS** PAINTS, SHELLAC, AND STAINS.	4.8
28	ALL CHEMICALS AND ALLIED PRODUCTS	100.0

SOURCES: U.S. DOC/BOC: STATISTICAL ABSTRACT OF THE U.S., 1984
EOP/OMB: STANDARD INDUSTRIAL CLASSIFICATION MANUAL, 1972

TABLE 7-2

SUBDIVISIONS AND CHARACTERIZATION OF THE CHEMICAL AND ALLIED PRODUCTS INDUSTRY (SIC 28) DURING 1980, IN 1972 DOLLARS

SUBDIVISION	PERCENTAGE CONTRIBUTION	NUMBER OF EMPLOYEES (1,000)	NUMBER OF ESTABLISHMENTS[a]			GROSS VALUE OF FIXED ASSETS ($/EMPLOYEE)	NEW CAPITAL EXPENDITURES ($/EMPLOYEE)	LABOR PRODUCTIVITY ($/EMPLOYEE)
			TOTAL	LESS THAN 20 EMPLOYEES	100 OR MORE EMPLOYEES			
ALL CHEMICALS (28)	100	909.7	12,173	7,550	1,516	50,366	5,403	45,829
INDUSTRIAL IN-ORGANIC CHEMICALS (281)	11	114.5	1,282	792	178	48,506	4,993	42,942
PLASTICS MATERIALS SYNTHETICS (282)	14	151.7	551	128	208	67,733	7,626	36,060
DRUGS (283)	17	172.6	1,243	761	220	24,750	2,930	43,806
SOAP, CLEANERS TOILET GOODS (284)	17	122.0	2,528	1,783	219	21,786	2,451	58,516
PAINTS AND ALLIED PRODUCTS (285)	5	62.3	1,579	926	145	16,616	1,848	32,020
INDUSTRIAL ORGANIC CHEMICALS (286)	23	155.1	879	369	264	100,377	10,613	56,718
AGRICULTURAL CHEMICALS (287)	7	55.5	1,325	843	114	60,121	7,164	57,548
MISC. CHEMICAL PRODUCTS (289)	6	75.9	2,786	1,948	168	24,932	2,945	34,490

[a] 1977

SOURCE: U.S. DOC/BOC: CENSUS OF MANUFACTURES, 1977
U.S. DOC/BOC: ANNUAL SURVEY OF MANUFACTURES, 1981

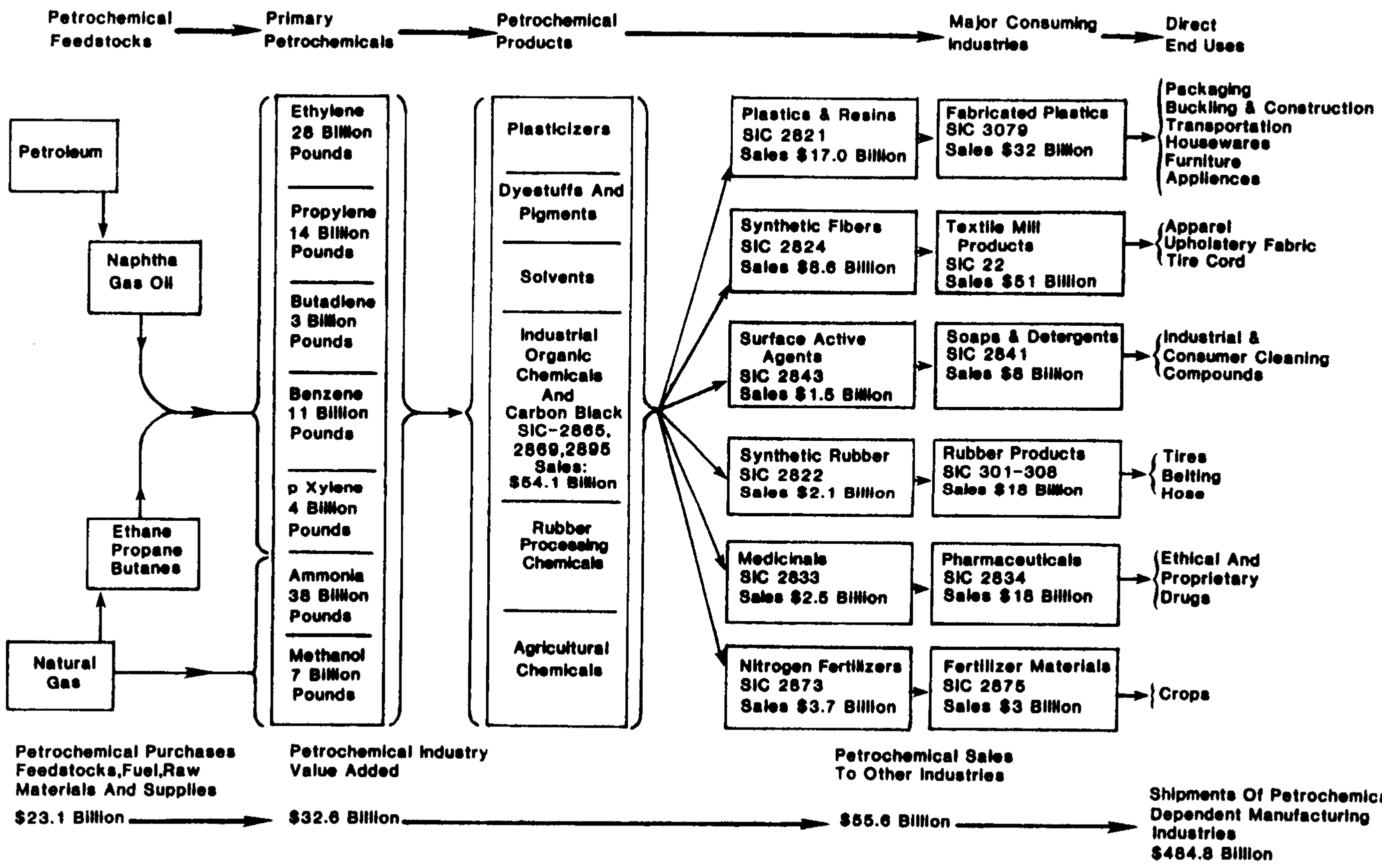


Figure 7-1. Structure of the Petrochemical Industry

fibers. Major sources of revenue include fabrics and textiles, paper products, paints, tires and inner tubes, rubber products and miscellaneous manufacturing.

Tables 7-3 and 7-4 illustrate the industry's business and structural profiles, respectively. Table 7-3 shows that industry shipments, expressed in constant 1972 dollars, increased by 25% over eleven years; however, this represented a drop from a shipment high of $14.5 billion in 1979 to $13.1 billion in 1983. Employment decreased by 23.3% during the same period. Plants operated at only 60% of capacity during the fourth quarter of 1982.

Tables 7-4 shows that the industry is dominated by five firms, which produced $20.4 billion in sales in 1983. Establishments are mostly intermediate in size with 68% employing 20 to 1000 workers.

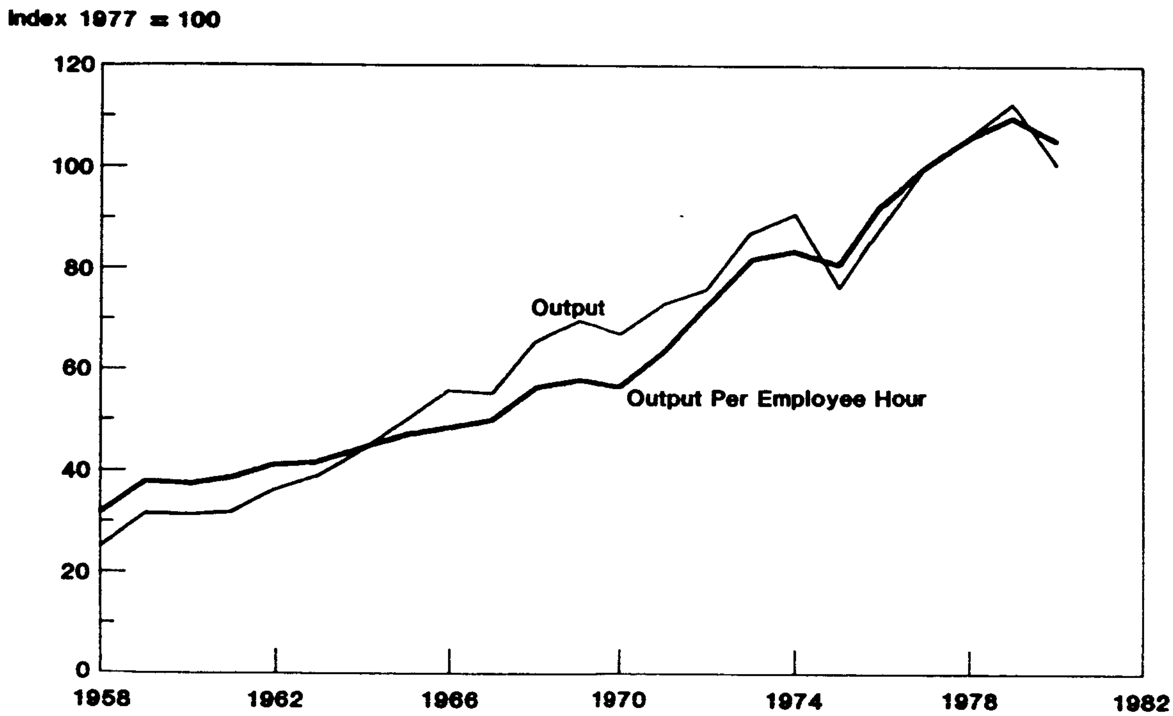
The cost of producing the finished product in this subdivision is dominated by the cost of input materials (72.9%). Total labor costs represent 16.4% of production costs, while energy and capital costs are 5.1% and 5.6%, respectively. Water has become a major cost factor in chemical processing. For the six years between 1972 and 1978, the average annual cost of water pollution control was $13.4 billion. Yearly projections for the period from 1981 to 1990 are expected to average $112.0 billion.

The plastics and synthetics subdivision (SIC 282) can be broken down into constituent subgroups for a clearer picture of trends in production, imports, and exports. The four subgroups of the plastics and synthetics industry are the plastics materials industry (SIC 2821), the synthetic rubber industry (SIC 2822), and the man-made fibers industries: cellulosic fiber (SIC 2823) and noncellulosic fibers (SIC 2824). A more detailed analysis of these industries follows.

TABLE 7-3

BUSINESS PROFILE OF THE
PLASTICS MATERIALS AND SYNTHETICS INDUSTRY (SIC 282)

SHIPMENTS (BILLION $)	1972	1977	1979	1981	1983
CURRENT $	9.8	20.0	26.4	30.7	30.9
1972 $	9.8	12.7	14.5	13.1	13.1
TOTAL EMPLOYMENT (THOUSANDS)	161.6	157.2	160.2	147.1	131.3



Source: Unpublished BLS Data

OPERATING CAPACITY, 1982, %	60
NET PROFIT MARGIN AFTER TAXES, 1981, %	4.6
MEDIAN EQUITY RETURN, 1983, %	16.4
NEW CAPITAL EXPENDITURES, 1981 (BILLION $)	1.60

SOURCES: U.S. DOC/BIE: 1984 U.S. INDUSTRIAL OUTLOOK
U.S. DOL/BLS
ARTHUR D. LITTLE, INC.

TABLE 7-4

STRUCTURAL PROFILE OF THE
PLASTICS AND SYNTHETIC RESIN INDUSTRY (SIC 282)

ESTABLISHMENTS (1977 (CATEGORIZED BY NO. OF EMPLOYEES)		**LEADING FIRMS (1983)** NAME	SALES ($ BILLION)
SMALL (<20)	128	E.I. DUPONT de NEMOURS, INC.	13.6
INTERMEDIATE (20-1000)	365	MONSANTO CO.	2.55
LARGE (>1000)	43	CELANESE CORP.	2.48
		HERCULES INC.	0.95
TOTAL (319 COMPANIES)	536	OWENS-ILLINOIS	0.86
		TOTAL	20.44

	MFG. LABOR	OTHER LABOR	MATERIALS	ENERGY	CAPITAL
PRODUCTION COST DISTRIBUTION, 1980	11.8%	4.6%	72.9%	5.1%	5.6%

PREVALENT MODE OF PROCESSING CONTINUOUS WITH SOME BATCH

R&D EXPENDITURES, (1981 ESTIMATED) CURRENT $, BILLION	0.75

AVERAGE ANNUAL COST OF WATER POLLUTION CONTROL (MILLION 1972, $)	1972-78	1981-90
	13.4	112.0

BACKLOG, 1981	52.2 DAYS

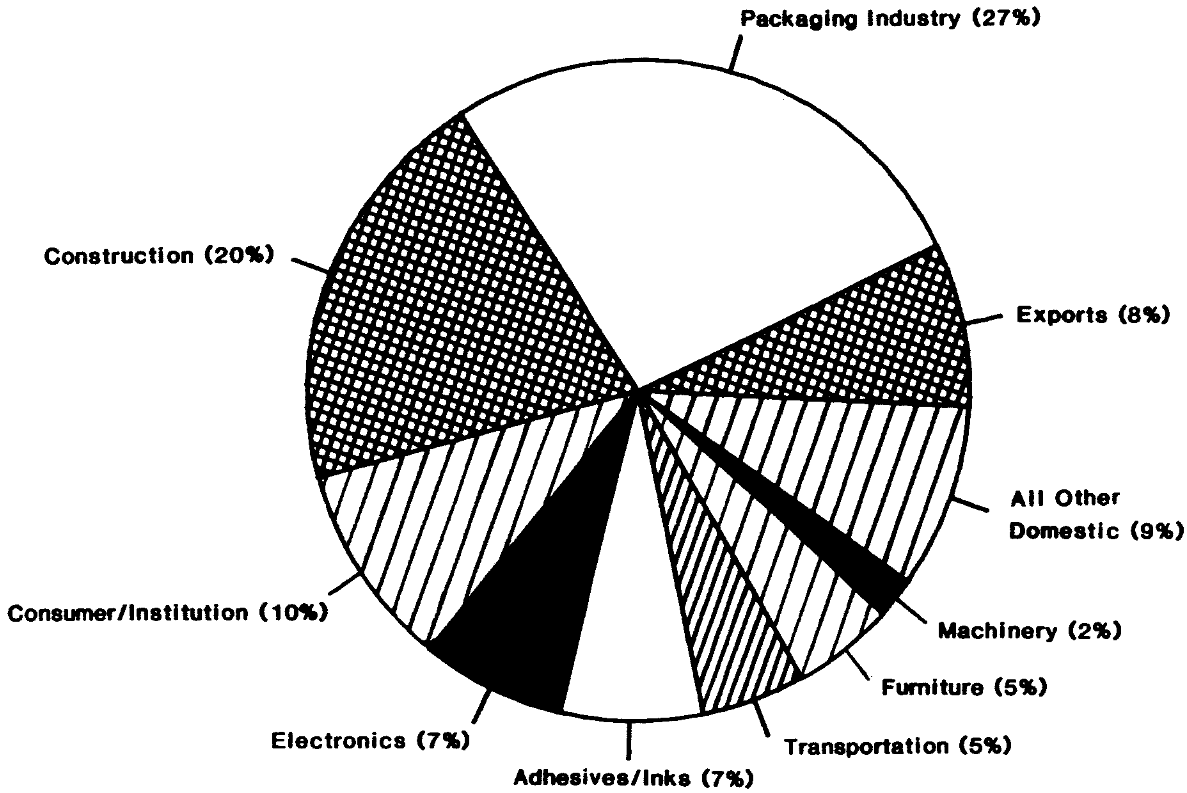
SOURCES: U.S. DOC/BIE: 1984 U.S. INDUSTRIAL OUTLOOK
EPA: 1984 COST OF CLEAN AIR AND WATER REPORT TO CONGRESS
1984 VALUE-LINE INVESTMENT SURVEY

Plastics materials (SIC 2821) are organic polymers which can be molded or formed into many different products with a wide variety of physical and chemical properties. The largest percentage of production in the plastics materials industry (70%) is dominated by polyvinyl chloride (PVC), low density polyethylene (LDPE), and polypropylene (PP). Shipments of plastics (in constant 1972 $) increased from $4.4 billion in 1970 to a peak of $5.6 billion in 1979; then dropped to $5.0 billion in 1980, $5.2 billion in 1981 and $4.4 billion in 1982, before rising to $4.85 billion in 1983.

Employment in the plastics materials industry has varied little (less than 1%) during recent years. In 1983, total industry employment in 1983 was 53,600. Only 22% of industry establishments (87 out of 397) employ less than 20 workers.

Production workers account for about 62% of total industry employment. The production rate for the plastics materials industry has risen despite the unchanged employment situation, with plants producing polypropylene nearing 90% of capacity in 1983, polycarbonate production facilities up to 80% of capacity, and acrylonitrile-butadiene-styrene plants operating at 85% of capacity. Since most plastic plants are highly automated the need for a limited supply of production workers remains constant, regardless of how close to capacity the plants operate. In response to a state of overcapacity in 1983, European producers considered a coordinated reduction in capacity. In the U.S. new capital expenditures are low in spite of the higher production rates.

The value of U.S. plastics exports in 1983 fell 6% below the 1982 level as a result of the strong dollar and the slow foreign market recovery. Although imports rose slightly in 1983, the U.S. plastics industry is still the main supplier to domestic markets, with imports accounting for less than 2% of supply. Figure 7-2 shows that domestic demand is made up of the packaging



Source: Bureau Of Industrial Economics,
1984 U.S. Industrial Outlook

Figure 7-2. Breakdown of Plastics Consumption by Various Industries

industry (27%), the building and construction industry (20%), the consumer and institutional sector (10%), electronics (7%), and other domestic markets (28%). Exports account for the other 8% of total demand. Future growth in the plastics industry will be contingent upon overall U.S. industrial growth and any change in petroleum and other material costs (which contribute approximately 73% of production costs).

Within the man-made fiber industry, noncellulosic fibers (SIC 2824) contribute 90% of output and employ 80% of the total workforce. Nylon and polyester make up approximately 80% of noncellulosic output. In the cellulosic fiber industry (SIC 2823), rayon and acetate are the major products, comprising 62% and 38% of industry output, respectively. Between 1972 and 1979, shipments by both man-made fiber producers, measured in 1972 dollars, increased 80%. From 1979 to 1982 the real value of shipments decreased 21%, however, in 1983 the value of shipments (in 1972 $) increased 11% over 1982. Total industry capacity utilization rates average 66%. The per capita demand for man-made fibers has decreased 22% in recent years as a result of high interest rates, the recession, and reduced cotton prices.

Man-made fiber exports (measured in 1972 $) fell 28% from 1982 to 1983, while imports rose 59%, leaving a positive balance of trade of $646 million, down 38% from 1982 to 1983, while imports also fell 13%. Noncellulosic fiber exports also declined by 29% to $161 million. The domestic market for U.S. man-made fibers is much larger than the export market for these fibers: Exports comprise 5% of cellulosic shipments; imports comprise only 2% of all U.S. man-made fiber consumption. However the rapid decline in the positive balance of trade in 1983 indicates an alarming rate of market loss.

Employment in cellulosic fibers has also been declining since 1979, decreasing 6% in 1983. Total employment in noncellulosic fibers decreased 8% from 1982 to 1983.

Rubber is a curable elastic material. The synthetic rubber industry (SIC 2822) consists of 60 production establishments producing rubber-like materials and specialty rubber. The four largest companies produce 60% of industry shipments. The two largest producing states are Texas and Louisiana, because of their proximity to raw materials sources, i.e., petroleum refineries. Total industry employment is small (on the order of 10,000 employees); half of the 60 production establishments are staffed by 20 workers or less.

Total industry shipments of synthetic rubber peaked at 6 billion pounds in 1979, declined in 1980 to 5 billion pounds, declined again in 1982 to 4.5 billion pounds, and then rose to 4.6 billion pounds in 1983. The value of export shipments has dropped an average of 14% per year since 1981, while the value of imports has risen only slightly (less than 5% since 1981). Synthetic rubber demand will grow 10% in 1984, while prices for materials and finished products will also rise. Material costs for the synthetic rubber industry account for 70% of the value of shipments.

The main constraints on the synthetic rubber industry growth are raw materials costs, efficiency of process innovations, and new materials development costs. At least 60% of synthetic rubber is used to manufacture tires; thus, a large factor in rubber production is new car production and motor vehicle use.

Competitive Issues Affecting the U.S. Plastics and Synthetics Industry

In general, U.S. plastics and synthetics industry exports are declining while imports are increasing slowly each year. This trend is a result of the strong U.S. dollar, as well as the saturation and sluggish economic condition of foreign markets. The largest gain in U.S. imports has been in the man-made fibers industry, which has opened more plants in developing countries, with large amounts of raw materials, government subsidies, and little or no domestic markets for finished products. The largest amount of this foreign investment activity by U.S. firms has been in Europe. Conversely, European firms have made heavy investments in American production facilities. Japan has been investing in firms in Hong Kong, Korea, Taiwan, and the petroleum-rich countries.

Since materials are such a large part of production costs, the U.S. will find itself competing for the foreign suppliers with available petroleum reserves. An increasing portion of petroleum-producing states are also operating refineries, where plastics and synthetics are most economically produced. U.S. plastics materials (SIC 2821) have increased their share of world markets in recent years, while the U.S. share of the world market of man-made fibers and synthetic rubber has decreased. Dominant constraints affecting this industry are summarized in Table 7-5.

Productivity in the Plastics and Synthetics Industry

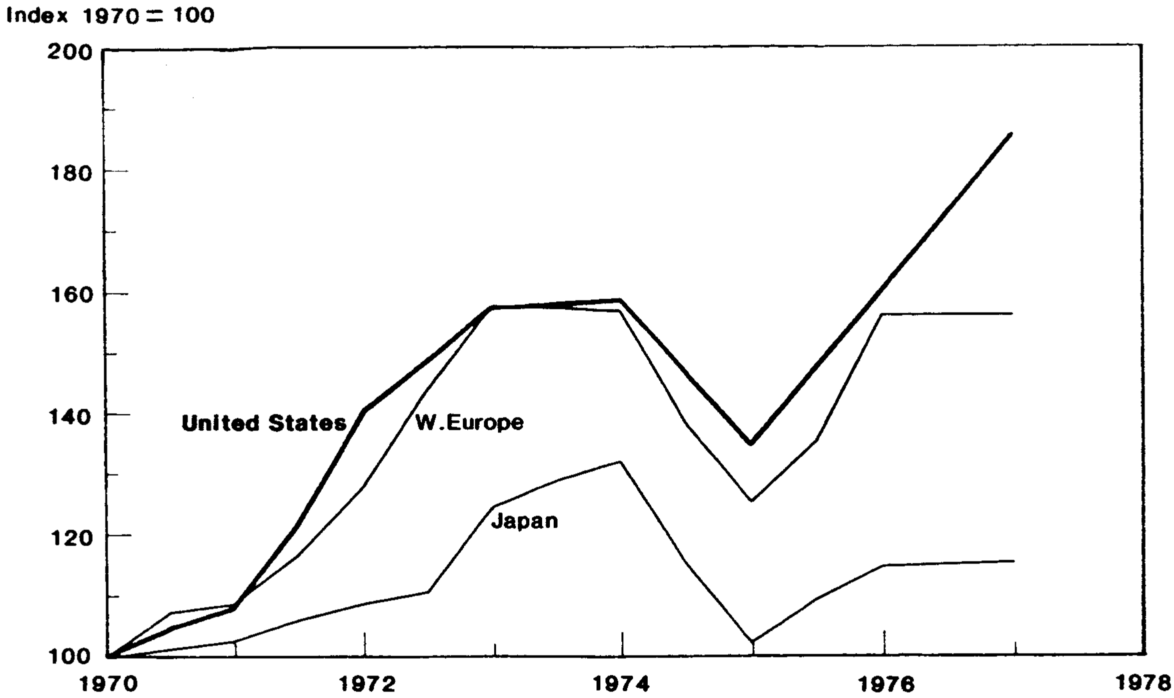
The petrochemical industry is one of the most highly energy-intensive and capital-intensive manufacturing industries. In 1980, in the plastics materials and man-made fibers industries, material costs accounted for more than 70%; capital costs about 6%; energy costs 5%; and, labor costs 16.5% of production costs. Industry employment has been gradually decreasing while productivity has increased during the past decade. From 1970 to 1980, fuel prices increased by 550%, while feedstock prices increased by a range of 250% to 700%. Economy-of-scale applies to the plastics materials and synthetics industry, with large plant size and technologically improved manufacturing processes contributing to plant competitiveness and efficiency.

Figure 7-3 shows a consistent productivity pattern in the plastics and synthetics industry among Western European countries, the U.S. and Japan. The U.S. leads in production as a

TABLE 7-5

DOMINANT CONSTRAINTS AFFECTING THE PLASTICS AND SYNTHETIC RESINS INDUSTRY (SIC 282)

GOVERNMENT REGULATIONS	NUMEROUS CONCERNED WITH HAZARDOUS WASTE AND WORKER SAFETY: CLEAN AIR AND WATER ACT, OHSA.
FUEL AND FEEDSTOCK PRICES	AVERAGE ENERGY REQUIREMENTS FOR PROCESS USE, BUT EXPENSIVE HYDROCARBON FEEDSTOCKS HAVE GREATEST EFFECT ON PRODUCT PRICES.
LABOR STRUCTURE	STEADILY DECLINING EMPLOYMENT DISCOURAGES JOB SEEKERS. SHORT (3 TO 6 MONTHS) WORKER TRAINING PERIOD.
PRODUCTIVE ESTABLISHMENT	ADEQUATE FACILITIES AND MANAGEMENT COMPETENCE, BUT SHORTAGE OF TRAINED PERSONNEL FOR MOST ADVANCED PROCESS CONTROLS EXISTS.
FISCAL/MONETARY POLICY	STRONG DOLLAR IMPACTS CHEMICAL EXPORTS.
CAPITAL	LOW INVESTMENT RISK AND GOOD RATE-OF-RETURN FOR ENGINEERING PLASTICS, HIGH RISK AND LOW ROI FOR COMMODITY RESINS. CYCLICAL CASH FLOW IN COMMODITY RESINS.



Source: OECD, The Chemical Industry, Paris, 1978

Figure 7-3. Trends in Production in the Plastics and Synthetics Industry

TABLE 7-6

GROWTH IN ENGINEERING PLASTICS

RESIN	U.S. PRODUCTION, 1000 METRIC TONS 1980	1981	1985	1990
ACRYLONITRILE BUTADIENE STYRENE (ABS)	416	441	575	720
THERMOPLASTIC POLYESTERS	230	270	415	750
NYLON (NONFIBER)	123	132	200	320
POLYCARBONATE	106	111	150	210
ACETALS	40	42	52	68
OTHER ENGINEERING RESINS	153	171	240	360
TOTAL	**1,068**	**1,167**	**1,632**	**2,428**

SOURCE: CHEMICAL ENGINEERING, AUGUST 23, 1982.

result of a wide technological base and its use of domestic feedstock. The figure in Table 7-3 illustrates this steady rise of U.S. productivity (output per employee hour) in the plastics industry. "Productivity has increased faster in larger firms in all segments in all countries " (Ref. 1).

Role of Technology in Long-Term Strategic Outlook for Plastics Materials and Synthetics Industry

The plastics materials and synthetics industry has matured in line with the growing international control of production and sales following a virtual U.S. monopoly on these products at the end of the WWII. Demand will continue to rise for plastics that replace conventional materials (brick, wood, metal) and for engineering plastics (such as copolymers, blends of polymers, and composites) with high strength, excellent electrical characteristics, resistance to wear, impact, corrosion, and high temperature properties. Projected growth in engineering plastics is summarized in Table 7-6. Increases in automobile production and travel, building, electronic component manufacturing, packaging, and apparel manufacturing will all contribute to this growth of the plastics materials and synthetics industry in the short and long term. For these reasons, this subdivision of "Chemicals and Allied Products" is identified as a "sunrise" industry.

If the 1983 economic pace is maintained, plastic materials (SIC 2821) shipments, measured in 1972 dollars, are expected to rise 7% in 1984. Shipments are expected to continue to rise at an average annual rate of 5 to 6% throughout the 1980s. Higher operating rates for plants are expected to increase this industry's profitability. U.S. plastic production may reach 55 billion pounds by 1987. The high cost of R&D may slow growth trends, but innovation will yield higher productivity. Foreign plastics producers with favorable raw materials reserves, however, will cut into foreign markets, and may affect domestic markets as imports grow in importance. "The future of commodity plastics, which make up 70% of total plastics production, may be affected by foreign competition " (Ref. 2).

The man-made fibers industry (SIC 2823-2824) has witnessed several growth trends in technology. The first trend was initiated in the 1940s with the development of new, man-made fibers (e.g., polyester). The second trend, beginning in the 1960s and continuing into the 1970s, was characterized by the larger role assigned to equipment manufacturers in developing new and faster production technologies. This era saw the U.S. lose some of its role as major industry leader as equipment manufacturers sold their technological advances.

Composite plastics, especially plastics bonded with other materials to improve their structural strength without adding to their weight, are expected to be a key area for R&D as the variety of their applications grows. Carbon fiber, produced by subjecting petrochemical-based fibers to intense heat, will be applied increasingly to new composite manufacturing as economies of scale warrant their use. Carbon fiber prices have dropped about 93% from 1971 to $30 per pound in 1981. The production capacity of carbon fiber in the western developed countries will quadruple to 12 million pounds per year during 1981-1985, with half of this capacity increase occurring in the U.S. (Ref. 3). The use of polymer composites in airframe production is estimated to range from 7% to 65% by the year 2000, with 30% considered conservative. NASA estimates that if this reduces the weight of a plane by 12%, operating cost savings of 6% should result. Moreover, petrochemical-based composites are cheaper than metal matrix composites, and, the ability to mold these composites into complex shapes using lower amounts of energy than sheet-metal forming is making them increasingly competitive despite their high cost. One current estimate projects that by 1990 engineering plastics will have a 23% cost advantage over aluminum, and a 48% advantage over zinc (Ref. 4).

The oil crunch in the 1970s ushered in the third trend in man-made fiber production technology, characterized by a reduction in production costs by lowering energy requirements and more efficiently utilizing feedstock. The current trend will see the emphasis once again on product innovation; although no major, totally new fibers will be developed in the future, combinations of existing fibers and better value fibers (such as Gortex and hydrophilic plastics) will be produced. Most of this innovative technology will be produced by the major fiber firms rather than by equipment manufacturers (Ref. 5).

The synthetic rubber industry (SIC 2822) shows the least promise for continued growth. Rapid increases in prices of crude oil and other fuels will reduce the demand for synthetic rubbers by the automobile industry, and lead to energy saving measures within the subdivision. Thus, while exports and imports will rise slightly in the immediate future, market saturation is forecasted, and quantitative growth in pounds shipped by the industry will be low.

Technological advances in coal gasification should improve the outlook for domestic feedstock production and reduced materials costs.

Table 7-7 summarizes technological issues, emerging technologies, and technological impacts on the plastics and synthetics industry.

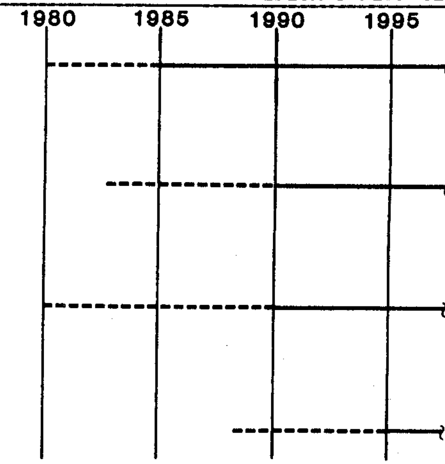
Summary

The plastics materials and synthetics manufacturing subdivision is a sunrise industry. Demand for this subdivision's products shows great promise for continued, steady growth. The primary constraint affecting the growth of this subdivision is expensive feedstock prices. Government regulations also tend to lower the profitability of new products, but these have a greater impact on feedstock suppliers.

TABLE 7-7

EMERGING TECHNOLOGIES IN PLASTICS AND SYNTHETICS

TECHNOLOGY	DESCRIPTION	APPROXIMATE ERA OF SIGNIFICANT DIFFUSION
L. P. CATALYTIC POLYMERIZATION	THIRD-GENERATION ZIEGLER-NATTA CATALYSTS DEVELOPED IN 1970s FOR LOW PRESSURE POLYOLEFIN PROCESS.	
INTERPENETRATING POLYMER	PHYSICALLY INTERLOCKED BENDS OF ENGINEERING PLASTICS WITH A VARIETY OF OTHER PLASTICS.	
LIQUID CRYSTALLINE POLYMERS	SELF-REINFORCING RESINS CONSISTING OF AN ORDINARY ENGINEERING PLASTIC SPIKED WITH A RELATIVELY LOW-COST ORGANIC MOLECULE.	
INTRINSICALLY CONDUCTIVE POLYMERS	INTRINSIC CONDUCTIVITY OBTAINED BY ADDITION TO DOPANT THAT IMPLANTS ELECTRON ACCEPTORS IN THE POLYMER MATRIX.	



----= 15% Diffusion

There are several leapfrog technologies that may enable this industry to develop faster than forecasted. For example, this industry is a major source of advanced materials, as well as custom multiproperty materials such as engineering plastics. Although some mention was made of the variety of applications available for advanced materials, these applications that have not been determined or developed yet. The development of custom multiproperty materials should help to replace strategic materials with more plentiful products. Biotechnology is another leapfrog technology that may enhance productivity in this industry. Finally, information rationalization would aid manufacturers as well as customers in selecting the most suitable material with the most desirable properties.

B.7.2 DRUGS (SIC 283)

This subdivision consists of establishments engaged primarily in the manufacture of medicinal and botanical chemicals, pharmaceutical preparations, and biological compounds. Major revenue sources include vaccines, serums, antibiotics, vitamins, and over the counter (OTC) pharmaceutical preparations.

Pharmaceutical preparations (SIC 2834) is the largest industry in this subdivision, accounting for approximately 80% of added value, 80% of 1983 industry shipments, and employing 77% of all drug industry employees. Small companies (less than 20 employees) account for over 60% of the industry establishments. The four largest companies account for 24% of industry shipments.

Pharmaceutical exports in 1983 were valued at $709 million, 26% above the 1982 value; while imports were valued at $78.2 million, a 92% increase. The increase in imports reversed the declining trend that began in 1979. The positive balance of trade in the industry climbed from $522 million in 1982 to $613 million in 1983.

The pharmaceuticals industry has introduced 70 new prescription drugs to the market since 1977. However, the number of prescriptions has risen only moderately, because of higher drug prices, the severe acceptance requirements by the Food and Drug Administration, and the fact that 125 prescription drugs have been given a proprietary (OTC) status. Proprietary drugs include cough and cold relievers, vitamins, first aid preparations, antacids, and laxatives; the leading prescription drugs are the various antibiotics. "Sales of OTC drugs increased 11% in 1982 to $5.5 billion, because of trends towards more self-medication, more promotional education of consumers, new multi-symptom products, and more products being switched from prescription to proprietary status."(Ref. 6).

The medicinals and botanicals industry (SIC 2833) is dominated by its four largest companies, which accounted for 65% of industry shipments in 1983. Exports in 1983 were valued at $1.36 billion, up 6% from 1982; imports rose 11% to $1.12 billion. Since 1981, the positive balance of trade in the industry has decreased 12% yearly to the current level of $241 million.

The current dollar values of medicated feed additives in this industry increased slightly in 1983, while the actual number of shipments decreased. With the use of antibiotics in feed under review by U.S. regulatory agencies, chemical companies are hesitant to develop new products. As a result, the use of antibiotics in feed decreased 10% during 1982. "Of 35 new drug entities available in Europe for use in animal feed, none is permitted for use in the United States" (Ref. 7).

The biologicals industry (SIC 2831) exports were valued at $470 million during 1983, 4% above 1982 values, while imports increased 20% to $40.6 million. With vaccine-producing firms in the U.S. reduced to five, advanced immunization techniques and continued worldwide demand for new vaccines will foster competition within the biologicals industry.

Tables 7-8 and 7-9 detail the business and structural profiles respectively of the drug industry. Table 7-8 shows that drug industry shipments, expressed in constant 1972 dollars, have increased nearly 63% in the eleven year period from 1972 to 1983. The net income of the drug industry was approximately 13% of net sales during 1982 and 1983, up from 10.9% in 1981. Despite the increased shipments, sales by major U.S. pharmaceutical firms, as a proportion of the world market, have decreased from 61% in 1959 to less than 35% in the 1980s.

The growth rate in U.S. drug industry employment has been leveling off during the last decade. The yearly employment growth rate for the first six years of the previous decade was 3.6%; from 1979 to 1981 it was 2%; since 1981 it has been approximately 0.2%.

The U.S. drug industry is constrained significantly by regulations imposed by the Food and Drug Administration (FDA). "The detail and pervasiveness of regulation in the U.S. are almost unique, both in comparison with U.S. regulations of other industries, and with foreign regulation of pharmaceutical markets" (Ref. 8). The legislative bases for pharmaceutical drugs are regulated in conjunction with the Food and Drug Act (1906), the Federal Food, Drug, and Cosmetic Act (1938), and the Kefauver-Harris Drug Amendment (1962). Congress and its constituents also control the introduction of new drugs, through antitrust policies, time-consuming patent approval requirements, and cumbersome and risky liability regimes for consumer product claims. Finally, FDA expectations and requirements for volume and quality of testing increase as the safety and efficiency of testing procedures improve.

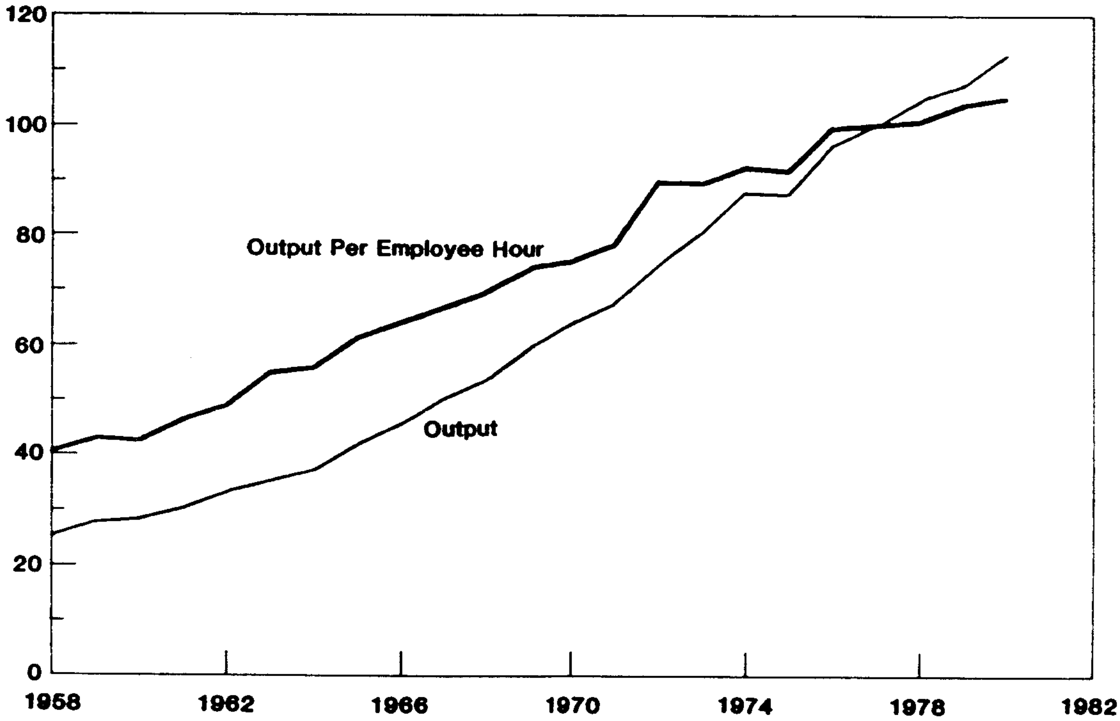
In August 1962, the FDA established procedures for investigational new drugs (IND). The Kefauver-Harris Amendment was passed to facilitate the application of these procedures; its central provisions are:

TABLE 7-8

BUSINESS PROFILE OF THE
DRUG INDUSTRY (SIC 283)

SHIPMENTS (BILLION $)	1972	1979	1981	1983	1982 EST.
CURRENT $	8.0	17.3	22.3	27.6	28.6
1972 &	8.0	11.6	12.4	13.0	13.5
TOTAL EMPLOYMENT (THOUSANDS)	129.9	163.1	169.7	170.5	170.7

Index 1977 = 100



Source: Unpublished BLS Data

	1983	1984
OPERATING CAPACITY, %	67	72-80
NET PROFIT MARGIN AFTER TAXES, 1981 BILLION $		3.17
MEDIAN EQUITY RETURN, 1983, %		12.6
NEW CAPITAL EXPENDITURES, 1981 BILLION $		1.05

SOURCES: U.S. DOC/BIE: 1984 U.S. INDUSTRIAL OUTLOOK
ARTHUR D. LITTLE, INC.

TABLE 7-9

STRUCTURAL PROFILE OF THE DRUG INDUSTRY (SIC 283)

ESTABLISHMENTS (1977)
(CATEGORIZED BY NO. OF EMPLOYEES)

SMALL (<20)	761
INTERMEDIATE (20-1000)	446
LARGE (>1000)	36
TOTAL (1058 COMPANIES)	1243

LEADING FIRMS (1983)

NAME	SALES (BILLION $)
AMERICAN HOME PRODUCTS	4.07
WARNER LAMBERT	3.5
AMERICAN CYANAMID	3.45
PFIZER	2.74
MERCK	2.73
ELI LILLY	2.55
ABBOT LABS	2.03
TOTAL	21.07

	MFG. LABOR	OTHER LABOR	MATERIALS	ENERGY	CAPITAL
PRODUCTION COST DISTRIBUTION, 1980	26.8%	11.7%	51.5%	3.0%	7.1%

PREVALENT MODE OF PROCESSING — BATCH

R&D EXPENDITURES, 1979 BILLION $ — 1.4

SOURCES: U.S. DOC/BIE: U.S. 1984 INDUSTRIAL OUTLOOK
ARTHUR D. LITTLE, INC.
1984 VALUE-LINE INVESTMENT SURVEY

- IND effectiveness must be demonstrated through "adequate and well-controlled investigations" prior to FDA approval.

- The FDA must monitor IND studies on humans through a Notice of Claimed Investigational Exemption, which, if vetoed, halts human testing.

- No automatic approval of a drug is possible after 90 days, as was common prior to 1962: The FDA must affirmatively approve a New Drug Application. (Ref. 9)

The following adjuncts to the Kefauver-Harris Amendment were added to regulate manufacturing practices:

- Preclinical guidelines for toxicity testing (1968);

- Regulations which specify the requirements for "well controlled investigations" to produce "substantial evidence" of the efficacy of IND (1970);

- 30 day delay for initiation of human testing of IND (1970);

- Expanded requirements for manufacturing and quality control (1972);

- Freedom of Information Act regulations (1975); and,

- The establishment of improved lab practice guidelines (1978).

These regulations have led to the increased cost of drug development because of the large outlays required to achieve successful R&D, and the additional delay in the payoff time for successful innovation. The current cost estimate for the development of a new drug, from conception to marketing, is $85 million; thus, the drug industry is compelled to undertake extensive pretesting and prudent selectivity prior to developing a new drug.

Dominant constraints affecting the drug industry are summarized in Table 7-10.

The regulation process in other countries is generally more flexible and prompt. Listed below are approximate mean times, for various countries, between an application for a new drug and its actual marketing (Ref. 10).

COUNTRY	MEAN APPLICATION PROCESSING TIME
U.K.	5 months
Canada	16 months
Norway	17 months
U.S.	**23 months**
Sweden	28 months

The following distinctions between U.S. and foreign pharmaceutical regulation procedures were noted in a 1980 General Accounting Office report:

- Foreign governments typically make frequent use of expert committees, some of which have sole responsibility for a new drug approval; by comparison, new drug applications are not submitted to FDA committees.

- Foreign governments tend to accept foreign data, depending on the source; the FDA traditionally disavows foreign data, using instead duplicate data as a basis for new drug application approval.

TABLE 7-10

DOMINANT CONSTRAINTS AFFECTING THE DRUG INDUSTRY (SIC 283)

GOVERNMENT REGULATIONS	PRIMARILY CONCERNED WITH NEW DRUG ENTITY APPROVAL. FDA APPROVAL ADDS TO DEVELOPMENT COSTS.
FUEL AND MATERIAL COSTS	LOW OR MODEST REQUIREMENTS HAVE MINOR IMPACT ON COMPETITIVENESS OF PRODUCT.
PRODUCTION ESTABLISHMENT	ADEQUATE FACILITIES AND MANAGEMENT COMPETENCE. LIMITED SUPPLY OF BIOCHEMISTRY MAJORS FOR WORKER REPLACEMENT.
FISCAL/MONETARY POLICY	STRONG DOLLAR HAS SLIGHT IMPACT ON EXPORT STRENGTH.
CAPITAL	SIGNIFICANT INVESTMENT RISK ($85 MILLION FOR EACH NEW DRUG ENTITY) OVER LONG R&D, AND FDA APPROVAL PERIOD, BUT HIGH RATE OF RETURN FOR UNIQUE INNOVATIONS. CONSTANT CASH FLOW REQUIRED.

- The drug approval process is less politicized in foreign countries; congressional and consumer scrutiny tends to slow this process in the U.S.

- Foreign governments foster cooperation between regulators and industry; the FDA favors an adversary relationship with industry, which compounds the communications problems associated with antitrust legislation (Ref. 11).

Competitive Issues Affecting the Drug Industry

In 1983, the U.S. drug industry accounted for 24% (approximately \$74 billion) of the world's total shipments of prescription and proprietary drugs. The U.S. drug industry has maintained a positive balance of trade, estimated at \$1.3 billion in 1983. U.S. pharmaceuticals sell well in foreign countries: some U.S. firms realize 40% to 50% of corporate sales from foreign subsidiaries. In addition, U.S. patent laws and FDA regulations have contributed to the good reputation abroad enjoyed by U.S. firms for product safety and efficacy.

The status of the U.S. drug industry, on the basis of accepted economic measures such as rates-of-return, is more difficult to assess. Because of the lengthy time span between product conception and marketing, the rate-of-return for the U.S. drug industry is a summary measure of past corporate performance, not an indicator of future industrial strength. A better measure of the industry strength is the extent and vitality of its R&D programs, particularly its research programs. The U.S. government expends more money on drug research than all other combined sources, both industrial and governmental, in the western developed nations. For instance, in 1972 the U.S. government spent \$2.2 billion on drug research (or 53% of worldwide research expenditures); for the same year U.S. industry contributed 14% of these worldwide drug research expenditures. The U.S. proportion of drug research articles written in 1977 was: 43% in clinical medicine, 39% in biomedicine, and 22% in chemistry. Although these U.S. expenditures for drug and pharmaceutical research at home and abroad are large and growing (by 1.1% per year), foreign research is beginning to outstrip American efforts.

This declining U.S. performance in pharmaceutical R&D can be attributed to non-tariff trade barriers in foreign countries and incentives and subsidies offered by foreign governments to industries that promote R&D. For example, in Japan a corporate tax credit of 20% is given to industries whose R&D expenditures from the previous year exceeded expenditures for any year since 1967. France and England have non-tariff barriers which exclude the sale of certain drugs manufactured outside of their borders, thus promoting native research, development and manufacturing efforts. FDA regulations, by contrast, serve as non-tariff barriers on exports and domestic products.

The relative position, worldwide, of the U.S. drug and pharmaceuticals industry is eroding. Imports rose 14.3% and exports by only 10.5% in 1983. At the same time consumer demands have grown more rapidly in foreign pharmaceutical markets vis-a-vis markets in the U.S., as indicated in Table 7-11. The restrictive non-tariff barriers set up by foreign governments prevent U.S. exports from being sold in their markets. While large U.S. industries entered these markets through their association with multinational corporations, smaller U.S. firms with limited resources are excluded from these markets, and are thus forced to cope with the slow expansion of the U.S. domestic market.

The decline in the U.S. percentage of annual world pharmaceutical production is illustrated in Table 7-12. The superior performances of Western Europe and Japan are shown in Figure 7-4.

TABLE 7-11

DOMESTIC PHARMACEUTICAL SALES AMONG SELECTED COUNTRIES (MILLIONS OF CURRENT $)

	1965	1970	1975	GROWTH (%)
U.S.	**3,121**	**4,701**	**7,387**	**9**
JAPAN	1,298	2,975	6,402	17
F.R. GERMANY	742	1,408	3,952	18
FRANCE	967	1,207	2,731	11
ITALY	514	920	2,181	16
SPAIN	236	597	1,652	21
U.K.	300	408	815	10

NOTES: GROWTH FIGURE IS ANNUAL PERCENTAGE GROWTH RATE. SALES ARE APPARENT CONSUMPTION (PRODUCTION PLUS IMPORTS MINUS EXPORTS) EXCEPT FOR U.S. AND U.K.

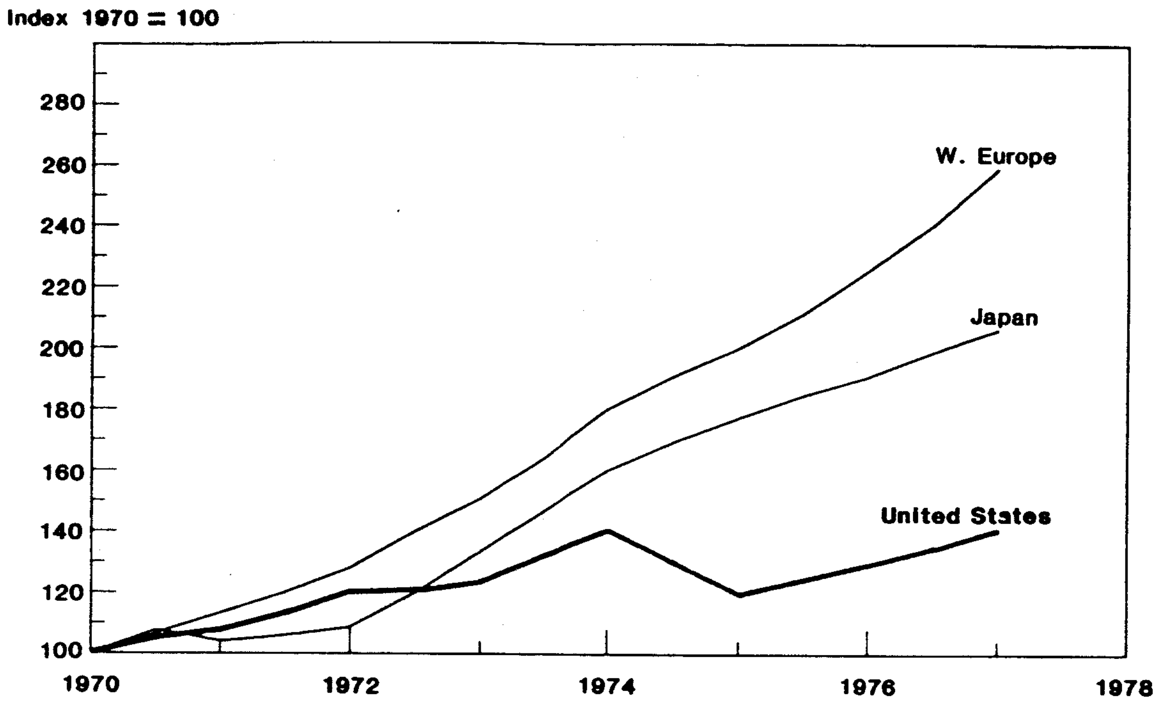
SOURCES: U.S. PMA, PRESCRIPTION DRUG INDUSTRY FACTBOOK, PMA, WASHINGTON, D.C., 1976
ABPI, ANNUAL REPORT, LONDON, VARIOUS YEARS.

TABLE 7-12

PERCENT ANNUAL WORLD PRODUCTION OF PHARMACEUTICAL PRODUCTS, 1968-1978

	1968	1970	1972	1974	1976	1978
U.S.	**38.0**	**35.0**	**33.0**	**29.0**	**30.0**	**27.0**
JAPAN	13.0	14.5	14.5	16.0	16.0	20.0
F.R. GERMANY	8.5	9.0	10.0	10.5	10.0	10.0
FRANCE	6.0	5.5	6.0	6.5	6.5	6.5
U.K.	6.0	5.5	5.5	5.5	5.0	5.5
ITALY	5.0	4.5	4.5	5.5	5.0	4.5
SWITZERLAND	2.0	2.0	2.0	2.5	2.5	3.0
OTHERS	21.5	24.0	24.5	24.5	25.0	23.5

SOURCE: BUNDESVERBAND DER PHARMAZEUTISCHEN INDUSTRIE, PHARMA JAHRESBERICHT, BPI, FRANKFURT, VARIOUS YEARS.



Source: OECD, The Chemical Industry, Paris, 1978

Figure 7-4. Trends in Production in the Drug Products Industry

Productivity in the Drug Industry

The majority of drug production cost (52%) was spent on materials (chemical feedstocks) in 1980; these costs are not expected to decrease, because of the lack of domestic sources of raw materials. The next largest portion of production cost (38%) was spent on labor, because of the labor-intensive nature of this industry. A high proportion of drugs is manufactured in small batch processes, which require a set number of employees no matter how low production rates are. Increases in demand for finished drug and pharmaceutical products force plants to operate closer to full capacity, which leads to increased productivity. The figure in Table 7-8, drawn from unpublished BLS data, shows that the labor productivity (output per employee hour) in the U.S. drug industry has been rising steadily over the past two decades, except for the slight leveling off trend that began in 1977.

However, as was previously indicated, imports of drugs to the U.S. are increasing due to a lack of U.S. R&D and the overvaluation of U.S currency. According to a National Academy of Engineering report, the U.S. drug industry has been losing its world leadership principally because of a declining number of new drugs under development.

In response to this situation, the U.S. is expanding its R&D efforts at home and abroad. However, since the cost of developing and marketing drugs in a competitive marketplace will continue to rise 5% per year, fewer drugs that treat the same illness are being developed, and more unique drugs will eventually become available. In addition, the greater emphasis on self-treatment will lead to a continued increase in OTC drug production.

Role of Technology in Long-term Strategic Outlook for the Drug Industry

All of the industries within the drug industry subdivision are growing, along with an attendant rise in employment. The value of biologicals shipments is forecasted to increase 5% yearly during the next decade. The leading product in the biologicals industry, diagnostic tests, will be faster, more efficient, and less costly; new oral vaccines will contribute to the profits of biologicals. The value of medicinals will increase 4.3% per year through 1988, with the introduction of new drugs for antiviral and anticancer chemotherapies. The demand for prescription and proprietary drugs will increase by 3.4% in value through 1988. In two-thirds of all visits to a physician a prescription is issued, and a shift in emphasis from surgery to drug treatment has been evident in recent years. In addition, since the drug industry shows the most profit per dollar of sales (13.1¢/$) of all nondurables, funds for R&D have been increasing substantial (by 20% from 1982 to 1983). "Worldwide sales of pharmaceuticals, estimated at $66 billion in 1980, are expected to climb to $100 billion (1980 $) by 1990" (Ref. 12). Therefore, the drug industry is identified as a "sunrise" industry.

Key technological advances in the drug industry are being targeted to raise plant efficiency by increasing production rates, reducing feedstock waste, improving process yields, lowering energy consumption, enhancing new chemical separation and water removal techniques, and tightening process controls through the application of computer-aided manufacturing (CAM) technologies. Biotechnology promises to produce new products and innovative processes. CAM systems, coupled with newer and more accurate instrumentation and faster machinery, facilitate increased productivity, and higher profitability. R&D of new chemicals and new technologies will be accelerated in the near future. Remote sensing instrumentation, developed for the space program, will be applied to process control. The high cost of material will lead to the development of new sources of feedstock from domestic raw materials. Continuous production techniques such as enzymatic reactors could significantly streamline production methods. Examples of emerging technologies that will have an impact on the drug industry are listed in Table 7-13.

Summary

The drug industry is identified as a sunrise subdivision. Steady growth is expected as consumers buy more OTC drugs. There is always a market for truly unique innovations, especially those developed to treat illnesses or conditions for which there are no drug entities, or for which the current product has unfavorable side-effects. Investment risks are high for new products, but the return-on-investment is the highest of all nondurable products.

Potential leapfrog technologies applicable to the drug chemicals industry are biotechnology and information rationalization. Biotechnology may enable the streamlining of the production process as well as providing for a more diverse base of feedstocks. Information rationalization techniques that are best suited for this industry's needs are extensive medical databases for optimum selection of treatment and expert systems that will grow more precise for aiding in diagnosis and prescribing treatments. A pharmaceuticals database and an expert system for optimizing the production and registration process from conception to marketing by identifying the critical path(s) are conceivable goals that have the potential to reduce manpower needs for innovation, production, and marketing.

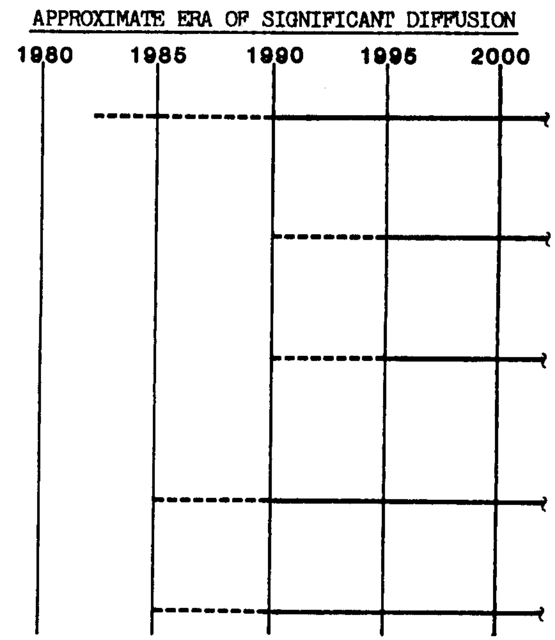
B.7.3 INDUSTRIAL ORGANIC CHEMICALS (SIC 286)

This subdivision, consisting of establishments engaged in the manufacture of industrial organic chemicals, includes noncyclic organic chemicals and their metallic salts, solvents, poly-

TABLE 7-13

EMERGING TECHNOLOGIES IN THE DRUG INDUSTRY

TECHNOLOGY	DESCRIPTION
DELIVERY SYSTEM	USE OF SITE-SPECIFIC, BIODEGRADABLE DRUG CARRIERS INCLUDING MACROMOLECULES, HORMONES, LECITHIN, CARBOHYDRATES.
ENZYMATIC REACTORS	USE OF FLUIDIZED-BED AND OTHER REACTOR TECHNOLOGY TO CARRY OUT BIOLOGICAL REACTIONS CONTINUOUSLY.
IMMOBILIZED ENZYMES	ATTACHING ENZYMES TO A POLYMER BACKBONE FOR USE AS SUPPORTED CATALYSTS IN BIOREACTORS.
BIOPROCESS ENGINEERING	
● SEPARATION PROCESSES	INCREASING RECOVERY EFFICIENCY OF PRODUCT SEPARATION TO REDUCE LOSSES AND IMPROVE PURITY.
● SENSORS/CONTROLS	DEVELOPMENT OF IMPROVED SENSING DEVICES TO MONITOR ENZYMATIC REACTIONS.



----=15% Diffusion

hydric alcohols, synthetic perfume and flavoring materials, rubber processing chemicals (both cyclic and acyclic), cyclic and acyclic plasticizers, synthetic tanning agents, chemical warfare gases, esters, amines, etc. of polyhydric alcohols and fatty acids, cyclic crudes and intermediates, cyclic dyes and organic pigments, and natural gum and wood chemicals. Organic chemicals are defined as compounds of carbon. They are divided into two categories based on their chemical structure: cyclic or aromatic organic compounds (SIC 2865), and acyclic or aliphatic organic compounds (SIC 2869). The major large volume cyclic petrochemicals are benzene, toluene, and xylene; major large volume acyclic petrochemicals are ethylene, propylene, and butadiene. Acyclic industrial organic chemicals are further classified as primary and intermediate petrochemical materials. Primary compounds are the first stage of petrochemicals produced directly from feedstock hydrocarbons; these are used mainly for the production of organic, intermediate chemicals. Additional industrial organic chemicals that are produced from wood distillation product feedstock are categorized under Gum and Wood Chemicals (SIC 2861).

Acyclic Organic Chemicals NEC (SIC 2869) represent the largest industry within the industrial organic chemicals subdivision, in terms of value of shipments and total employment. In 1983, this industry employed about 78% of the total work force and accounted for approximately 82% of the value of industry shipments, 84% of the value added, 73% of the value of industry exports, and 46% of the value of industry imports within the industrial organic chemical subdivision. The value of industry shipments, in constant 1972 dollars, increased steadily from 1970 to 1981 (except for a plateau reached in the late 1970s, reflecting a similar trend in fuel and feedstock prices) at an average annual rate of 3%, decreased by 5% in 1982, rebounded to a 4.2% increase in 1983, and is projected to increase by 9% in 1984.

Cyclic organic chemicals (SIC 2865) are the second largest subgroup of industrial organic chemicals (SIC 286). In 1983, the cyclic crudes and intermediate chemicals industry employed 25,700 workers, or 19.1% of the total industrial organics workforce. During that same year, cyclic organic chemicals accounted for 14% of the value of industrial organics shipments, 16% of value added, 25% of the value of industry exports, and 52% of the value of industry imports. The growth rate in the industry shipment value of cyclic crudes and intermediate chemicals has followed the same trend as acyclic chemicals. The average yearly growth rate from 1970 to 1981 was 2.5%, followed by a 12.1% decline in 1982 and a 1.4% increase in 1983. The predicted growth rate from 1983 to 1984 is 5.5%. The rise in value of shipments is a reflection of the rise in the cost of hydrocarbon feedstocks (especially petroleum).

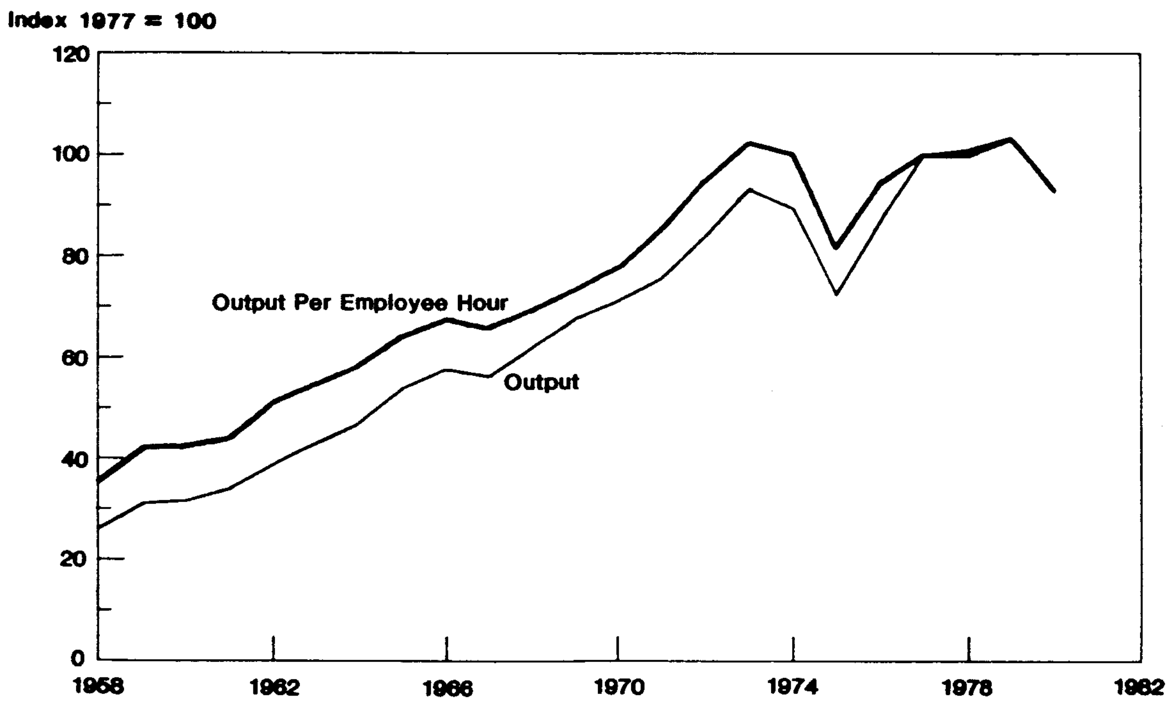
The gum and wood chemicals industry (SIC 2861) currently employs 3.3% of the industrial organics workforce and accounts for 4.2% of industry shipments. This subgroup produces 1.7% of industrial organics industry exports, and takes in 1.2% of industry imports. The constant-dollar value of shipments by the gum and wood chemicals industry increased by 2% in 1983 after a drop of 10% in 1982. This industry consists of 100 companies operating 119 establishments, only 35 of which employ 20 or more employees. The negligible contribution of this industry may be attributed to the fact that it must compete with synthetic materials produced in greater quantities by the petrochemical industry.

Tables 7-14 and 7-15 detail the business and structural profiles respectively of the industrial organic chemical industry. Table 7-14 shows that the value of industry shipments rose steadily from 1972 to 1979, then fluctuated from 1980 to 1983. Employment has decreased about 3% per year since 1979. The period from 1979 to 1980 witnessed a pronounced increase in the quantity of U.S. exports of cyclic and acyclic organic chemicals, which resulted from the availability of low-priced feedstock in the U.S. (due to U.S. price controls and a weak U.S. dollar).

TABLE 7-14

BUSINESS PROFILE OF THE INDUSTRIAL ORGANIC CHEMICALS INDUSTRY (SIC 286)

SHIPMENTS (BILLION $)	1972	1977	1979	1981	1982	1983	1984 EST.
CURRENT $	11.6	30.3	39.4	47.2	25.9	41.4	44.8
1972 $	11.6	13.7	14.3	13.4	12.5	13.0	14.1
TOTAL EMPLOYMENT (THOUSANDS)	136.5	152.8	151.8	147.5	N/A	134.5	141.4



Source: Unpublished BLS Data

OPERATING CAPACITY, %	1981	1983 (1ST QUARTER)
	74	63

NEW CAPITAL EXPENDITURES 1981 (BILLION $) 3.3

SOURCE: U.S. DOC/BIE: 1984 U.S. INDUSTRIAL OUTLOOK
ARTHUR D. LITTLE, INC.

TABLE 7-15

STRUCTURAL PROFILE OF THE INDUSTRIAL ORGANIC CHEMICALS INDUSTRY (SIC 286)

ESTABLISHMENTS (1977) (CATEGORIZED BY NO. OF EMPLOYEES)	
SMALL (<20)	369
INTERMEDIATE (20-1000)	478
LARGE (>1000)	32
TOTAL (623 COMPANIES)	879

LEADING FIRMS (1983)

NAME	SALES (BILLION $)
UNION CARBIDE	9.99
DOW CHEMICAL	9.25
GLANESE	3.14
HOOKER CHEMICAL	2.54
KOPPER CO.	1.92
WITCO CHEMICAL	1.72
TOTAL	28.56

	MFG. LABOR	OTHER LABOR	MATERIALS	ENERGY	CAPITAL
PRODUCTION COST DISTRIBUTION 1980	8.9%	4.0%	67.0%	7.6%	12.6%

PREVALENT MODE OF PROCESSING	CONTINUOUS
R&D EXPENDITURES 1979 (BILLION $)	2.018

SOURCE: U.S. DOC/BIE: 1984 U.S. INDUSTRIAL OUTLOOK
ARTHUR D. LITTLE, INC.
1984 VALUE-LINE INVESTMENT SURVEY

TABLE 7-16

DOMINANT CONSTRAINTS AFFECTING THE INDUSTRIAL ORGANIC CHEMICALS INDUSTRY (SIC 286)

GOVERNMENT REGULATIONS	MAINLY ENVIRONMENTAL POLICIES (CLEAN AIR ACT, OSHA) REGULATING POLLUTION EMISSIONS.
FUEL AND FEEDSTOCK PRICES	AVERAGE ENERGY REQUIREMENTS FOR PROCESS USE, BUT A HIGH DEMAND FOR EXPENSIVE HYDROCARBON FEED-STOCKS EXISTS.
LABOR STRUCTURE	DECLINING EMPLOYMENT DISCOURAGES JOB SEEKERS. SHORT (3-6 MONTHS) TRAINING PERIOD.
FISCAL/MONETARY POLICY	STRONG DOLLAR IMPACTS EXPORTS.
CAPITAL	SIGNIFICANT INVESMENT RISK WITH LIMITED RATE OF RETURN. CYCLICAL CASH FLOW.

U.S. trade in industrial organic chemicals is competetively vulnerable to government subsidized industries in developing countries, which can set prices below profitable levels, especially if these countries have domestic feedstock and fuel sources. Thus, prior to the introduction of U.S. price controls, fuel and feedstock prices skyrocketed during the 1970s, which accelerated the rising cost of cyclic and acyclic chemicals: "... the price of natural gas and distillate fuel oil, used as energy sources, increased by more than 550%. During this same period, propane and naptha feedstock prices increased by more than 700%. Also during this period, primary acyclic organic chemical prices rose 420%, while the price of cyclic organic intermediates increased by 250%" (Ref. 13).

Industrial organic chemicals are mainly derived from petrochemicals. The petrochemical industry is one of the most highly regulated in the U.S. Laws governing the petrochemical industry include the National Environmental Policy Act, the Toxic Substance Control Act of 1976, the Resource Conservation and Recovery Act of 1976, the Occupational Safety, and Health Act of 1970, the Clean Air Act, the Clean Water Act, and the Comprehensive Environmental Response Compensation Liability Act of 1980 (known as the superfund). These laws have helped improve plant efficiency in the U.S. petrochemical industry by requiring the installation of environmentally-sound processing equipment. The impact of the Toxic Substance Control Act is minimal on primary and intermediate chemical producers since no new discoveries are predicted in this area; however, new downstream and specialty products may be affected by this regulation.

Dominant constraints affecting the industrial organic chemicals industry are summarized in Table 7-16.

Competitive Issues Affecting the Industrial Organic Chemicals Industry (SIC 286)

Foreign trade in organic chemicals in 1983 was affected by the continued poor market conditions overseas and the strong position of the U.S. dollar in relation to foreign currency. U.S. exports of organic chemicals declined 11% in 1983, while imports rose 24%. The U.S. positive balance of trade in organic chemicals fell 35% from 1981 to 1983 to a value of $2.8 billion.

Japan and Western Europe are currently the primary competitors and trading partners in organic chemicals with the U.S. During the 1960s and 1970s, international interdependency of world organic chemical industries developed as a result of low fuel and feedstock prices, rising demand, and lack of government interference in petrochemical industry strategy planning. This climate is rapidly changing as countries reassess their positions on natural resource exploitation and management, the role of the petrochemical industry in their industrial base, the perceived need for self-sufficiency in certain industries, and the role of exports in national economies (Ref. 14). The U.S. organic chemicals industry may find itself competing with government subsidized industries, or industries with more favorable natural resource reserves.

Japan has developed a comprehensive program to make its organic chemicals industry more competitive. The scope of this strategy entails:

- replacing old plants with larger and more advanced facilities;
- reducing unneeded basic chemical capacity (including primary and intermediate organics) in order to shift resources to the specialty chemical area;

- developing relationships with fuel and feedstock suppliers in exchange for Japanese technology;
- developing R&D efforts to apply sophisticated technology to new feedstock sources and to the production of high-value specialty chemical products;
- developing a strong business/government relationship sponsored by Japan's Ministry of International Trade and Industry (MITI);
- encouraging the direct financial support of R&D programs by the Japanese government; and,
- initiating a policy of government-sponsored financial support of major international joint ventures in organic chemical development (Ref. 15).

This comprehensive joint program by Japan's industry and government is expected to make its petrochemical industry very competitive with the U.S. industry in Asian markets, and, in the long term, in U.S. domestic markets.

The competitive posture of the U.S. petrochemicals industry should not be affected by its compliance with health, safety, and environmental regulations. Most foreign competitors must comply with similar regulations; new plants in many developing nations have already incorporated state-of-the-art technology to increase environmental and production efficiency.

U.S. R&D interest in the chemicals and allied products industry has shifted away from primary and intermediate chemicals to downstream products. For example, the goal of catalyst research is to reduce production costs by reducing temperature, pressure requirements, and reaction times. The goal of biotechnology research is the development of biocatalysts for producing organic chemicals.

"Annual R&D expenditures in the chemicals and allied products industry during 1972-1979 increased by more than 28% (in constant dollars) as opposed to an 18% increase for all U.S. industry" (Ref. 16). U.S. research in this industry accounted for 15% of all industry R&D expenditures for 1981 (although this industry accounted for only 2% of the GNP) (Ref. 17). The private sector contributed 90% of these research funds.

The world price of fuels and feedstocks affects the profitability of U.S., European, and Japanese chemical industries. Natural gas, a key petrochemical feedstock, is difficult to transport without large capital outlays for equipment. Currently, refineries in oil-rich developing countries are flaring their natural gas. For countries like Saudi Arabia, the effective cost of supplying feedstocks for their organic chemicals industry is essentially determined by the cost of installing a natural gas gathering system (Ref. 18).

A competitive edge in the petrochemical industry must be attributed to Saudi Arabia, given their high capital expenditures and fierce national pride. However, joint economic ventures by western firms, in cooperation with governments in other hydrocarbon-rich developing countries (such as Mexico, Indonesia, and the Persian Gulf states), are also bringing new competitive petrochemical industries on line.

Future competition in the industrial organic chemicals industry will be among hydrocarbon-rich developing countries. The production of major commodity petrochemicals in these hydrocarbon-rich countries, in 1982, equalled about 10% of combined U.S. European, and Japanese production; by 1990, this figure may reach 25% (Ref. 19). Beyond 1990, only limitations on time and capital will dictate the market share of hydrocarbon-rich countries.

Productivity in the Industrial Organic Chemicals Industry (SIC 286)

The figure in Table 7-14, drawn from unpublished BLS data, shows that productivity (output per employee hour) in the U.S. industrial organic chemicals industry rose steadily, at an average rate of about 4.5% per year, from 1958 to 1973. From 1973 to 1975, the industry experienced a 22% decline in productivity as a result of the first U.S. gasoline "crisis." From 1975 to 1979, the industry then re-established its 1973 productivity levels. Between 1979 and 1980, the productivity once again fell 11% as a result of the worldwide recession. It should be noted that these productivity levels follow the same pattern as industry output; productivity drops when petrochemical plants are not running at or near full capacity because of the constant minimum staff requirements.

Materials costs account for approximately 67% of U.S. industrial organics production costs; energy costs amount to an additional 7.6%. However, the U.S. is the third largest producer of natural gas and has a domestic fuel and feestock supply. In Japanese and Western European industrial organics industries, materials account for an even larger proportion of production costs. By comparison, industries in hydrocarbon-rich countries can make their products more cheaply because of lower material costs.

Industrial organics is the most capital-intensive industry in the chemicals and allied products subsector; capital costs amount to 12.6% of production cost, while labor amounts to 12.9%. Capital is spent to increase plant efficiency (for compliance with environmental regulations), and to develop processing technology. In hydrocarbon rich countries, capital costs are even higher proportionally because of lower fuel and feedstock costs.

Following the most recent recession, the output of the U.S. primary industrial organic chemical industry has not rebounded to 1979 levels. Table 7-17 enumerates the total U.S. production of primary organic chemicals during the past decade.

TABLE 7-17

PRIMARY ORGANIC CHEMICAL PRODUCTION
(MILLION POUNDS)

PRODUCTION	**1972**	**1977**	**1979**	**1981**	**1982**	**1983**
BENZENE	8.7	10.0	11.8	9.6	7.9	9.0
TOLUENE	6.6	7.3	7.2	6.1	7.6	7.1
XYLENES	5.3	6.2	7.4	6.7	5.6	5.5
ETHYLENE	20.9	25.4	29.9	29.4	24.7	27.0
PROPYLENE	8.5	13.3	14.2	13.5	12.3	13.0
BUTADIENE	3.5	3.3	3.6	3.0	1.8	2.2
OTHER PRIMARY	33.3	40.2	46.5	41.2	36.7	40.0
TOTAL	**86.8**	**105.7**	**120.6**	**109.5**	**96.6**	**103.8**

SOURCE: U.S. INTERNATIONAL TRADE COMMISSION

Role of Technology in the Long-Term Strategic Outlook

The U.S. industrial organic chemicals industry is identified as a stable industry. While production of primary and intermediate organic chemicals is increasing, a growing share of the market is being taken over by industries in hydrocarbon-rich countries. "Greatly increased prices due to higher fuel and feedstock prices are already limiting demand growth in the more mature markets of industrialized countries" (Ref. 20). As a result, U.S. petroleum and chemical firms will gradually shift the majority of their production of commodity chemicals to foreign locations. Growth for the next several years should be about 5% annually. The greatest opportunities for demand growth will occur in the downstream development of pseudocommodity and specialty chemicals.

"There is no technological fix on the horizon that would appear to be able to overcome the fuel and feedstock advantages of hydrocarbon-rich countries" (Ref. 21). New forms of feedstock production (synthetic gas or coal gasification and biomass) will not be competitive with the low natural gas prices available in hydrocarbon-rich countries. Near-term feedstock needs may be partially met by improving the processing of heavy residues left over from gasoline and light fuel production. Biomass technology would require the production of biological catalysts, such as enzymes capable of converting cellulose to primary and intermediate organic chemicals and alcohols.

However, technological improvements in U.S. processing technologies are expected to favorably affect feedstock utilization. Biotechnology will yield biocatalysts that will enable reactions to take place at lower-temperatures and in less pressurized environments. The improved process technologies required to make bioprocessing feasible include:

- increased volumetric rates of reaction;
- improved yield coefficient ratios;
- an increased number of process steps in a single reaction vessel; and,
- a reduction in the number of reaction and recovery steps (Ref. 22).

In addition, Japan's Ministry of International Trade and Industry (MITI) is sponsoring a seven-year research program aimed at improving four major C chemistry research areas:

- techniques for generating and purifying synthesis gas;
- new synthesis processes for ethylene glycol, ethanol, and acid;
- new methods for making lower-molecular-weight compounds; and,
- the development of new catalysts (Ref. 23).

New strategic technological issues affecting the industrial organic chemicals industry are summarized in Table 7-18.

The most promising areas for industrial growth in the U.S. organic chemical industry are in such downstream products as pseudocommodities and specialty chemicals.

Summary

The industrial organic chemicals subdivision is neither a sunrise nor a sunset industry. Although projected growth is 5% per year for the next seven years, the U.S. industrial organic chemicals industry is not in a position to compete with increasingly industrialized hydrocarbon-rich countries that have cheaper and more abundant feedstock supplies.

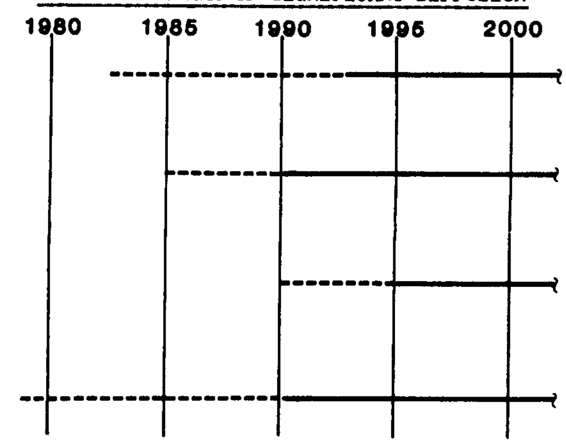
There are no leapfrog technologies identified for this manufacturing subdivision. Demand for industrial organic chemicals should rise as these are utilized in advanced and custom multi-property materials. Biotechnology holds the promise of reducing feedstock cost as well as process steps, but this technology will not offer advantages of significant enough magnitude to identify it as a leapfrog technology.

TABLE 7-18

EMERGING TECHNOLOGIES IN INDUSTRIAL ORGANIC CHEMICALS

TECHNOLOGY	CONDITION/DEFICIENCIES
C^1 CHEMISTRY	BUILDING BASIC HYDROCARBON INTERMEDIATES FROM MIXTURES OF HYDROGEN AND CARBON MONOXIDE.
ZEOLYTE CATALYSTS	SHAPE SELECTIVE POURS IN ALUMINA SILICATE MATRIX (ASSOCIATED WITH C^1 CHEMISTRY).
ENZYMES	ENZYMATIC CONVERSION OF BASIC CHEMICALS TO INTERMEDIATES AND SPECIALTY CHEMICALS (ENZYMES DO PRECISELY WHAT IS WANTED)
SEPARATION	LOW ENERGY, HIGH EFFICIENCY LIQUID AND GAS SEPARATION TECHNIQUES (MEMBRANES, ADSORPTION, ETC.) TO SAVE ENERGY

APPROXIMATE ERA OF SIGNIFICANT DIFFUSION



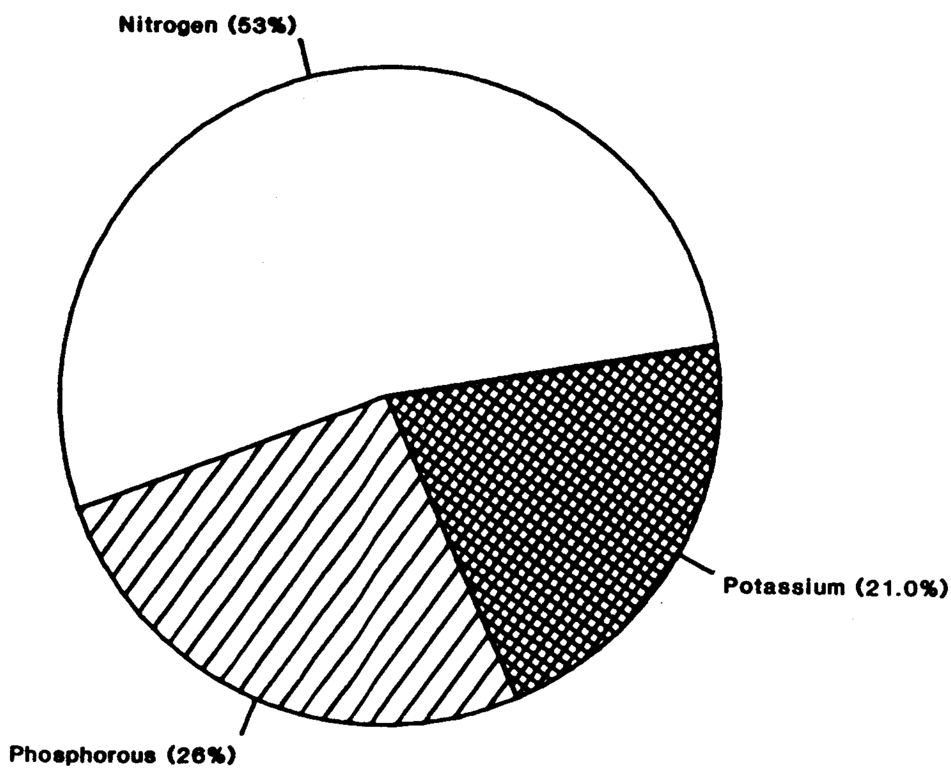
---- = 15% Diffusion

B.7.4 AGRICULTURAL CHEMICALS (SIC 287)

This subdivision includes establishments primarily engaged in the manufacture of basic nitrogenous and phosphatic fertilizers, mixed fertilizers, pesticides, and other agricultural chemicals.

Nitrogen, phosphorous, and potassium are the basic plant nutrients. Nitrogen fertilizer in its basic form is ammonia produced from natural gas and nitrogen. Phosphatic fertilizer is composed of phosphoric acid made from phosphate rock and sulfuric acid. Potassium is derived from potassium chloride (potash). A breakdown of world fertilzer consumption is shown in Figure 7-5.

The agricultural chemicals subdivision is subdivided into the nitrogenous fertilizer industry (SIC 2873), the phosphatic



Source: U.S. Department Of Industrial Economics
1984 Industrial Outlook

Figure 7-5. Breakdown of World Fertilizer Consumption by Fertilizer Type

fertilizer industry (SIC 2874), the fertilizer mixing only industry (SIC 2875), and the agricultural chemicals NEC industry (SIC 2879). The subdivision accounted for about 8% of the value added of all chemicals and allied products in the U.S. in 1983. Its positive balance of trade for this industry was $2.1 billion in 1982, $1.9 billion in 1983, and is expected to be $2.0 billion in 1984. Fifty-seven percent of its establishments employed 20 persons or less in 1977, while, at the same time, the four largest companies accounted for about 39% of industry shipments.

Table 7-19 presents the business profile of the agricultural chemicals industry. From the data it is evident that the industry has been in a depressed state since 1981. Prior to 1981, industry shipments were growing at an average annual rate of 4.5% (in constant 1972 $). From 1981 to 1983, the constant dollar value of shipments fell 12% per year. Although this constant dollar value of shipments is expected to climb 12% in 1984 to $4.8 billion (constant 1972 $), this is still about 13% below the peak value reached in 1981.

Employment in this industry rose at a steady rate of approximately 1.8% per year from 1972 to 1981, with the exception of a slight decline during the recession of 1979. From 1981 to 1983, employment fell 8% per year. In 1984, total industry employment is expected to rise 5% over 1983 values. In general, the industry is still a good risk, showing a median equity return of 15.8% in 1983.

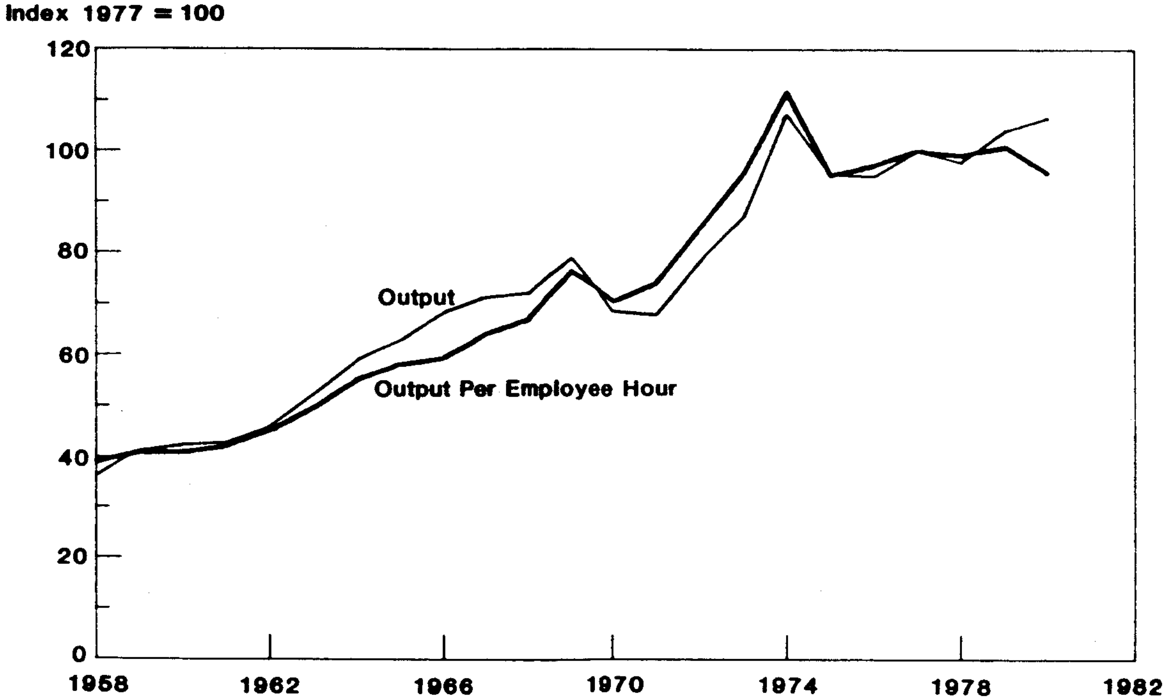
The structural profile of the agricultural chemicals industry is summarized in Table 7-20. The leading manufacturing firms in this industry are diversified chemical companies. Materials and energy represent the largest proportion of production costs, accounting for 73.5% and 6.8% respectively.

Nitrogenous fertilizer or ammonia production in 1983 was down 18% from 1982 to a level of 10.5 million short tons of

TABLE 7-19

BUSINESS PROFILE OF
THE AGRICULTURAL CHEMICALS INDUSTRY (SIC 287)

SHIPMENTS (BILLION $)	1972	1977	1979	1981	1983	1984
CURRENT $	3.9	9.9	12.2	16.3	12.6	14.1
1972 $	3.9	5.1	5.4	5.5	4.3	4.8
TOTAL EMPLOYMENT (THOUSANDS)	47.9	53.9	53.1	55.5	47.1	49.6



Source: Unpublished BLS Data

	1979	1982
OPERATING CAPACITY, %	75	55

NET PROFIT MARGIN AFTER TAXES, 1981 (%)	3.3%
MEDIAN EQUITY RETURN, 1983	15.8%
NEW CAPITAL EXPENDITURES, 1981 (BILLION $)	1.141

SOURCES: U.S. DOC/BIE: 1984 U.S. INDUSTRIAL OUTLOOK
ARTHUR D. LITTLE, INC.

TABLE 7-20

STRUCTURAL PROFILE OF
AGRICULTURAL CHEMICALS INDUSTRY (SIC 287)

ESTABLISHMENTS (1977)
(CATEGORIZED BY NO. OF EMPLOYEES)

SMALL (<20)	843
INTERMEDIATE (20-1000)	476
LARGE (>1000)	6
TOTAL (948 COMPANIES)	1325

LEADING FIRMS (1981)

NAME	SALES (BILLION $)
UNIROYAL	2.3
WILLIAMS	2.1
CIBA GIEGY	1.7
CF INDUSTRIES	1.2
CHEVRON	1.2
TOTAL	8.5

PRODUCTION COST DISTRIBUTION 1980

MFG. LABOR	OTHER LABOR	MATERIALS	ENERGY	CAPITAL
8.2%	3.5%	73.5%	6.8%	8.1%

PREVALENT MODE OF PROCESSING: FERTILIZERS-CONTINUOUS; PESTICIDES/HERBICIDES-BATCH

R&D EXPENDITURES, 1979 (BILLION $): 0.56

BACKLOG: 45 DAYS

SOURCES: U.S. DOC/BOC: CENSUS OF MANUFACTURES, 1977
1984 VALUE-LINE INVESTMENT SURVEY
ARTHUR D. LITTLE, INC.

nitrogen. The U.S. consumption of nitrogenous fertilizer was down about 12% in 1983 from 1982. The value of product shipments for 1983 was $4 billion, down 12% from 1982, while the compound growth rate, in constant 1972 dollars, was 1.5% per annum from 1972 to 1983. Prices stayed down in 1982 and 1983 as a result of reduced domestic demand and low cost imports. Expensive natural gas and depressed prices caused an 11% decline in capacity in 1983, following a trend started in 1979. The industry operated at 93% of total capacity in 1983. Natural gas price deregulation will continue to cause profits to be squeezed in the future.

Diammonium phosphate, containing two nutrients (20% nitrogen and 50% phosphorous), showed the most impressive gains of all fertilizers and agricultural chemicals in 1983; its exports rose 20%, accounting for nearly half of the total nitrogen exported. The 10% drop in the unit value of this fertilizer helped to make it competitive in foreign markets in spite of the strong dollar.

Production of phosphate rock rose 6% above its 1982 low in 1983, despite an expected 13% drop in consumption. Its compound annual growth rate in constant dollars from 1972 through 1983 was 0.3%. The value of phosphate rock shipped fell 14%, from 1982 to 1983, to $2.7 billion. The forecasted 1984 value of product shipments is expected to climb 15% (in constant 1972 $) over the value in 1983, but will still remain 24% below the 1980 high.

Mixed fertilizers are expected to follow the same pattern as other fertilizer products. The value of mixed fertilizer shipments fell 14% to $532 million in 1983, but is expected to rise 10% in 1984 to $585 million (in constant 1972 $).

Pesticides, including herbicides, fungicides, insecticides, and vermin poisons, showed a combined growth rate of 1.8% between 1972 and 1983 (in constant 1972 $). When combined with a price increase rate of 12.3% per year, this yields a growth rate in product value of 14.1% annually. While the constant dollar value for pesticides dropped 10% from 1982 to 1983, the value of product shipments is expected to increase 12% in 1984, with prices increasing moderately.

Federal regulation of pesticides was initiated with the Federal Insecticide Act of 1910, which focused primarily on overcoming adulteration and regulating labeling. In 1938, the Pure Food and Drug Act of 1906 was amended to cover pesticides in food, particularly to provide tolerances for residues of arsenic and lead and to color white insecticides in order to prevent them from being mistaken for flour. The Federal Insecticide, Fungicide and Rodenticide Act (FIFRA) of 1947, providing guidelines for labeling and displaying pesticide contents, superseded the 1910 act. In 1959, the FIFRA was amended to include plant growth regulators, defoliants, and dessicants. In 1972, the FIFRA was further amended as the Federal Environmental Pesticide Control Act (FEPCA) that categorized pesticides in terms of their general and restricted use, and required registration and inspection of pesticide manufacturers, distributors, and applicators. Additional pesticide legislation has included the 1954 Miller amendment to the Food, Drug and Cosmetic Act of 1938, and the Food Additives Amendment of 1958.

In the pesticides industry, ". . . there is a lapse of about seven years between the time a pesticide is synthesized and the time it is made commercially available. Research and development costs for each pesticide average $15 million" (Ref. 24). Patent life begins when the new chemical entity is synthesized and lasts 15 years; thus the approval procedure effectively halves the time period during which the entity can be profitably exploited.

As the demand for food rises, worldwide, so too does the demand for agrichemicals. However, the competitive position of the U.S. farmer in recent years, eroded because of the strong dollar coupled with rising grain prices, has constrained growth in the agricultural chemicals industry. In addition, poor weather has decreased farm productivity; the Payment-In-Kind (PIK) program has reduced the amount of U.S. cultivated farm acreage; and there is increasing competition for the U.S. ammonia market from countries with lower priced natural gas supplies.

Chief constraints affecting the agricultural chemicals industry are summarized in Table 7-21.

Competitive Issues Affecting the Agricultural Chemicals Industry

The U.S. leads the world in phosphate production, and 75% of U.S. fertilizer product shipments remain in the U.S. domestic market. The U.S.S.R. leads the world in nitrogen production, and Canada and the U.S.S.R. share the lead in potash production.

U.S. exports of phosphatic fertilizers rose 4% to over $1 billion (in current $) in 1983; imports were $54 million. Exports are expected to increase 10 to 15% in 1984 and to continue to rise into the early 1990s. However, production of Moroccan phosphates is increasing at a faster rate than U.S. production; thus, the growth rate of U.S. exports is expected to level off by the end of the century.

Total U.S. exports of nitrogenous fertilizers declined 20% from 1982 to 1983 to $511 million (in current $). Exports of diammonium phosphate rose over 20% in 1983. Imports of nitrogenous fertilizer rose 17% to $662 million in 1983, and exports are expected to drop 10% in 1984. Imports of ammonia in 1983 accounted for 50% of all nitrogen imports, but showed only a slight rise above 1982 levels. Urea accounted for 40% of all nitrogen imports, a 130% rise over 1982. The Soviet contribution to these nitrogen imports dropped 7% from 1982 to 1983, i.e., to a 22% share of U.S. imports.

The overall value of U.S. pesticide exports dropped about 5% (in current $) from 1982 to 1983. The compound annual growth

TABLE 7-21

CONSTRAINTS AFFECTING THE AGRICULTURAL CHEMICALS INDUSTRY (SIC 287)

GOVERNMENT REGULATIONS	DEREGULATION OF NATURAL GAS RESULTS IN HIGHER MATERIALS COSTS, WHILE ENVIRONMENTAL REGULATIONS AFFECT WASTE MANAGEMENT AS WELL AS PRODUCT DEVELOPMENT, ESPECIALLY FOR PESTICIDES.
FUEL AND FEEDSTOCK PRICES	AVERAGE FUEL NEEDS FOR PROCESS USE, BUT EXTREMELY HIGH REQUIREMENTS FOR HYDROCARBON FEEDSTOCKS.
LABOR STRUCTURE	STABLE OR DECLINING EMPLOYMENT OUTLOOK RESULTS IN DISINTERESTED JOB SEEKERS. SHORT (3-6 MONTHS) WORKER TRAINING PERIOD.
PRODUCTION ESTABLISHMENT	35% OF PLANTS AND EQUIPMENT ARE OVER 15 YEARS OLD.
FISCAL/MONETARY POLICY	STRONG DOLLAR REDUCES EXPORTS, BUT FAVORABLE TRADE AGREEMENTS WITH RUSSIA STABILIZE DEMAND.
CAPITAL	SUBSTANTIAL INVESTMENT RISK WITH LIMITED RATE-OF-RETURN AND FLUCTUATING CASH FLOW.

rate of pesticides exports from 1972 to 1983 was 16.6%. Exports constituted 28.3% of the value of product shipments in 1983; they are expected to rise 10% in 1984. Pesticide imports (in current $) did not change from 1982 to 1983, although the compound annual growth rate from 1972 to 1983 was 20.8%. Imports were 5.9% of supply and 7.8% of apparent consumption in 1983. Imports are expected to rise 5% in 1984. Generally, the decreasing export levels and increasing imports can be attributed to the strong U.S. dollar abroad.

Productivity in the Agrichemicals Industry

Material costs constitute the dominant agricultural chemical production cost, amounting to about 74% of the total. The primary agricultural chemical feedstock is natural gas, the price of which has been increasing as a result of deregulation. The U.S. is the world's third largest producer of natural gas, and there is also a large natural gas demand by other domestic industries.

Labor constitutes the next largest proportion of U.S. production costs (12%). The figure in Table 7-19 shows that labor productivity (output per employee hour) rose steadily from 1958 to 1974, at an annual rate of 4.5%. After 1974 productivity declined until 1977, where it remained at an approximately constant level.

The capital costs of agrichemicals in proportion to production costs are the second largest among the allied chemicals industries.

Role of Technology in Long-Term Strategic Outlook

As world population increases, the demand for food grows, which should lead to a rise in agricultural production. In its capacity to augment these increased agricultural production requirements, the agricultural chemicals industry must be considered a "sunrise" industry.

Key technological advances in the agricultural chemicals industry will include the development of plant growth regulators, biopesticides, biofertilizers, allelopathy, high efficiency ammonia processing techniques, and coal gasification. Growth regulators will be developed to aid a plant's ability to resist wind, heat, cold, drought, and salinity. Recombinant DNA technology will lead to the development of highly specific pesticides (called biopesticides) and nitrogen assimilating plants (biofertilization). Allelopathy will be used to improve a plant strain's resistance to natural herbicides. High efficiency ammonia and urea processing will reduce the energy consumed per ton of ammonia produced. Coal gasification will yield cheaper domestic feedstocks for ammonia production. These trends and the projected times of development are listed in Table 7-22.

Summary

Due to the demand for its products, the agricultural chemicals subdivision is categorized as a sunrise industry. Possible reversals in this subdivision's growth may result from the feedstock resource advantages of competing countries.

One leapfrog technology has been identified for this industry subdivision. Biotechnology may be utilized for enhanced feedstock production and recovery. Since feedstock prices account for almost three-quarters of the production cost, reduced feedstock costs offer significant savings if economically feasible to institute. Biotechnology may also be utilized to develop hardier plant strains which would greatly expand the agricultural chemicals market.

B.7.5 CONCLUSION

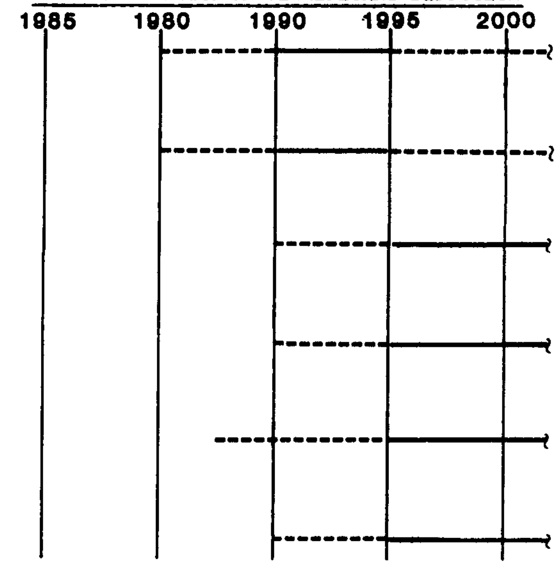
The majority of subdivisions within the chemicals and allied products subsector illustrate similar constraints and prospects. All of the subdivisions which have been discussed, except for

TABLE 7-22

EMERGING TECHNOLOGIES FOR ARGICHEMICALS

TECHNOLOGY	DESCRIPTION
HIGH EFFICIENCY AMMONIA PROCESS	PROCESS IMPROVEMENTS TO REDUCE ENERGY CONSUMED PER TON OF PRODUCT.
HIGH EFFICIENCY UREA PROCESS	PROCESS IMPROVEMENTS TO REDUCE ENERGY CONSUMED PER TON OF PRODUCT.
BIOPESTICIDES	DEVELOPMENT OF HIGHLY SPECIFIC PESTICIDES USING RECOMBINANT DNA TECHNIQUES.
BIOFERTILIZATION	DEVELOPMENT OF NITROGEN ASSIMILATING PLANTS BY GENETIC MANIPULATION.
ALLELOPATHY	IMPROVED STRAINS OF PLANTS WITH NATURAL HERBICIDE CHARCTERISTIC.
COAL GASIFICATION	USE OF COAL-DERIVED SYNTHESIS GAS FOR AMMONIA PRODUCTION.

APPROXIMATE ERA OF SIGNIFICANT DIFFUSION



---- = 15% Diffusion

industrial organic chemicals, are "sunrise" industries; industrial organic chemicals is a saturated industry facing severe foreign competition. Employment is declining steadily in all subdivisions except drugs. Governmental product licensing and environmental regulations affect all subdivisions, and effectively add to the product cost. The introduction of most new chemicals or related products entails significant investment risks, with limited returns-on-investment. Each subdivision, except for drug chemicals, has average process energy requirements but high feedstock requirements. Finally, the continued strength of the U.S. dollar depresses export activity for these subdivisions.

Long-term strategic recommendations for the subdivisions within the chemical and allied products subsector are as follows:

- Replace current feedstocks with economic coal gasification or biomass and develop nonpetroleum process routes.

- Where feedstock requirements and prices are high, develop higher value products such as engineering plastics, pseudocommodities, specialty chemicals, etc.

- Develop less-polluting processes and generic waste disposal techniques, preferrably with government assistance.

- Liberalize laws regarding joint development of technology. Develop more effective chemical product testing procedures.

- Optimize plant efficiency and value by rationalizing plant capacity based on market demands. Encourage development of better process management techniques.

- Seek government sponsorship of R&D in key areas.

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B.8 "PETROLEUM AND RELATED PRODUCTS" (SIC 29)

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SOURCES: U.S. DOC/BOC:

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LIST OF TABLES

B.8 "PETROLEUM AND RELATED PRODUCTS" (SIC 29)

The petroleum industry, Subsector 29, is the eighth largest manufacturing subsector; its value added accounted for 3.2% of the manufacturing sector's contribution to GDP in 1980. Note that oil and gas production is not reported under this two digit SIC classification. Statistical data on this part of the industry is reported under Crude Petroleum and Natural Gas (SIC 1311). The subsector is characterized by:

- A high degree of fragmentation. Out of a total of approximately 2,200 establishments, 1,400 employed less than 20 persons (1977).

- A labor productivity of $49,332 per employee year or $25.69 per employee hour (1980, 1972 $), ranking this subsector second among the nation's 20 manufacturing subsectors. A compound annual labor productivity growth rate average of 2.2%/year from 1972 to 1980 ranks this subsector fifth. The labor productivity for the comparable Japanese subsector was $34,288 per employee year or $17.86 per employee hour (1980, 1972 $), ranking this subsector first among Japan's 20 manufacturing subsectors. The compound annual labor productivity growth rate for the Japanese subsector averaged 4.2%/year from 1972 to 1980, ranking this subsector seventeenth.

- An extremely high capital investment base relative to other subsectors within the manufacturing sector. Capital investment amounted to $70,498 in total assets per worker, ranking first in terms of (depreciated) fixed assets (1980, 1972 $). New yearly capital expenditures were $7,184 per employee (1980, 1972 $), ranking first in the manufacturing sector. Total capital productivity, measured as dollars of added value output per dollar of capital investment, was 0.50 (1981).

- A moderately aggressive R&D program. For the subsector as a whole, R&D expenditures amounted to $0.9 billion (1980, 1972 $), ranking this subsector sixth among the 20 manufacturing subsectors. R&D expenditures were equivalent to 6.3% of the value added by the subsector in 1980.

Table 8-1 shows the major products produced by the subdivisions and each subdivision's share of the subsector's contribution to GDP in 1980. Table 8-2 summarizes the primary economic features of the principal subdivisions.

One subdivision--petroleum refining (SIC 291)--accounted for 89% of the subsector's output in 1980. In assessing long-term technology needs, this industry has been selected for detailed analysis.

B.8.1 PETROLEUM REFINING (SIC 291)

The petroleum refining begins with the processing of crude petroleum and natural gas liquid products, called feedstocks, into a variety of primary fuel products. These primary products such as gasoline, kerosine, jet fuel and diesel fuel are sold to other industry sectors or the general public.

Refining is defined as the physical and/or chemical separation of the hydrocarbon compounds in crude petroleum and natural gas liquid products, producing "lighter" "heavy" petrochemicals as the primary fuel products. This process is accomplished through combinations of thermal application, distillation, catalytic reforming, alkylation, hydrodesulfuration and hydrocracking.

TABLE 8-1

CLASSIFICATION OF MAJOR PRODUCTS OF THE PETROLEUM AND RELATED PRODUCTS INDUSTRY (SIC 29) AND CONTRIBUTION TO SUBSECTOR IN 1980

SIC CODE	SUBDIVISION DESIGNATION AND TYPICAL PRODUCTS	% CONTRIBUTION
291	**PETROLEUM REFINING** GASOLINE, JET FUEL, KEROSENE, DISTILLATE AND RESIDUAL FUEL OILS, LUBRICANTS, AND OTHER CRUDE PETROLEUM PRODUCTS	89.2
295	**PAVING AND ROOFING MATERIALS** ASPHALT AND TAR PAVING PRODUCTS, PAVING BLOCKS, CREOSOTED WOOD; ASPHALT AND SATURATED FELTS IN ROLLS OR SHINGLE FORM, ROOFING CEMENT, AND COATINGS	6.6
299	**MISCELLANEOUS PETROLEUM AND COAL PRODUCTS** REFINED LUBRICATING OILS AND GREASES, LUBRICATING OIL BASE STOCKS, FUEL BRIQUETTES, BOULETS, PACKAGED FUEL, POWDERED FUEL, AND OTHER PETROLEUM AND COAL PRODUCTS	4.2
29	ALL PETROLEUM AND RELATED PRODUCTS	100.0

SOURCE: U.S. DOC/BOC: STATISTICAL ABSTRACT OF THE U.S., 1982-83
EOP/OMB: STANDARD INDUSTRIAL CLASSIFICATION, 1972

TABLE 8-2

SUBDIVISIONS AND CHARACTERIZATION OF THE PETROLEUM PRODUCTS INDUSTRY (SIC 29) DURING 1980, IN 1972 DOLLARS

SUBDIVISION	PERCENTAGE CONTRIBUTION	NUMBER OF EMPLOYEES (1,000)	NUMBER OF ESTABLISHMENTS[a]			GROSS VALUE OF FIXED ASSETS ($/EMPLOYEE)	NEW CAPITAL EXPENDITURES ($/EMPLOYEE)	LABOR PRODUCTIVITY ($/EMPLOYEE)
			TOTAL	LESS THAN 20 EMPLOYEES	100 OR MORE EMPLOYEES			
ALL PETROLEUM PRODUCTS (29)	100	148.9	2,206	1,432	278	70,498	7,184	49,332
PETROLEUM REFINING (291)	86	102.7	349	69	182	96,130	9,733	63,820
PAVING & ROOFING MATERIALS (295)	9	31.3	1,297	969	78	13,995	1,165	15,435
MISC. PETROLEUM & COAL PRODUCTS (299)	5	14.4	560	394	18	12,960	1,835	22,249

a 1977

SOURCE: U.S. DOC/BOC: CENSUS OF MANUFACTURES, 1977
U.S. DOC/BOC: ANNUAL SURVEY OF MANUFACTURES, 1981

The petroleum refining industry is the major supplier of energy in the U.S. The industry faces pressure from environmental regulations, primarily concerning air pollution, and will face competition in the future from alternate energy sources such as geothermal, solar, coal, synfuel, nuclear, and hydroelectric.

Table 8-3 summarizes the projections of energy use by Standard Oil Co. of California (Chevron), one of the top petroleum refiners in the U.S. The data show that oil consumption will remain relatively flat through the year 2000; crude oil production will experience slow growth; consumption of alternate energy sources, such as coal and hydroelectric, will grow at a slow to moderate rate; nuclear energy consumption will grow at nearly 10% per year until 1990, before demand flattens.

TABLE 8-3

FUTURE GROWTH OF ENERGY CONSUMPTION AND PRODUCTION IN THE U.S.

ENERGY SOURCE	ANNUAL INCREASE (DECREASE), % 1983-1990	ANNUAL INCREASE (DECREASE), % 1990-2000
OIL CONSUMPTION	(0.3)	0.2
CRUDE OIL PRODUCTION	1.7	2.6
NATURAL GAS PRODUCTION	0.7	(1.3)
COAL CONSUMPTION	3.8	3.5
NUCLEAR CONSUMPTION	9.9	0.8
HYDROELECTRIC CONSUMPTION	2.2	2.2

SOURCE: STANDARD OIL CO. OF CALIFORNIA, WORLD ENERGY OUTLOOK

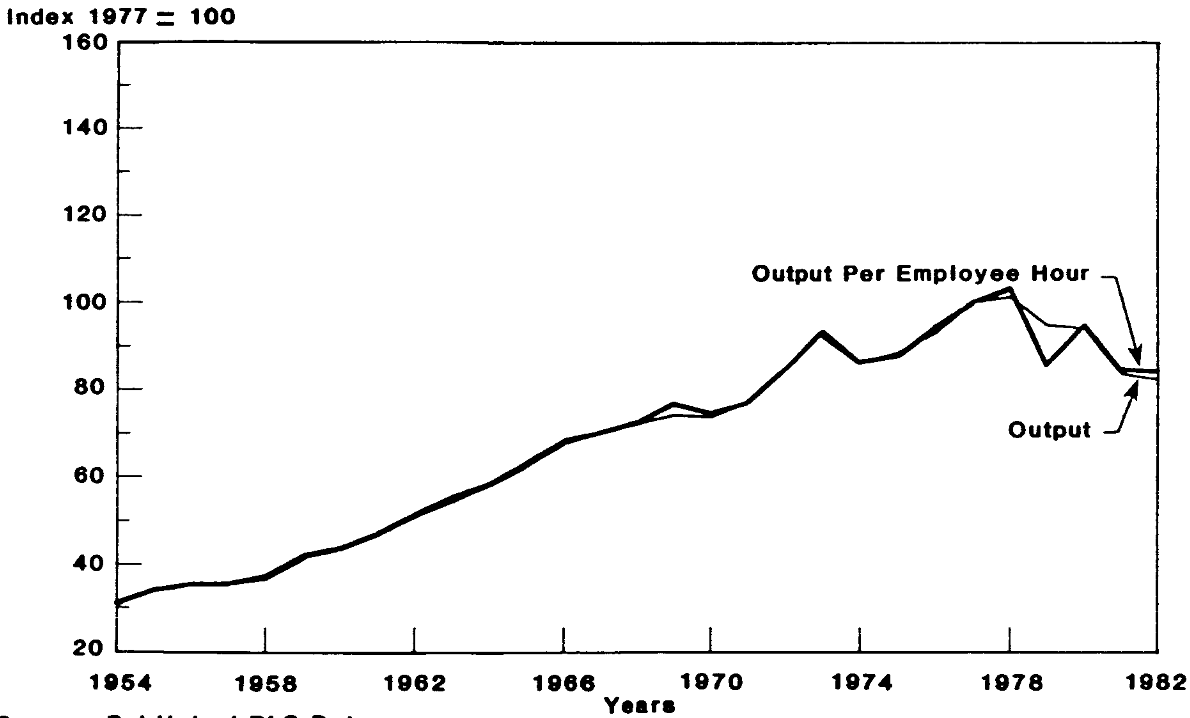
The petroleum refining subdivision's historical and current posture is summarized in Table 8-4 and 8-5, which portray the industry's business and structural profiles, respectively. Table 8-4 shows that the industry shipments, expressed in constant 1972 dollars have been essentially flat, varying between $26 and $35 billion during 1972-1983 period back to $28.6 billion in 1983. (Petroleum and petroleum products have inflated at a much greater rate than the economy as a whole. For example, the GNP price defaltor for 1983 is 200 (1972=100) while the deflator for petroleum refining is 600.) Shipment estimates for 1984 are $30.3 billion, up from $28.6 billion in 1983, but still within the range established during the past twelve years. Petroleum refining expressed in physical terms (barrels of refined oil shipped) has also remained flat; 4.8 billion barrels were shipped in 1972, virtually the same was shipped in 1983 (4.9 billion) and only a modest increase is estimated for 1984 (5.1 billion barrels). Employment has remained steady, while output and output/employee (i.e., productivity) has been slowly rising. New capital expenditures for petroleum refining technologies, expressed in constant 1972 dollars, have declined slowly from $1.1 billion in 1972 to $800 million in 1981. Refinery capacity has dropped from nearly full utilization in 1972 (99%) to 89% in 1983.

Table 8-5 shows that while most of the establishments in the petroleum refining industry are medium in size (20-1000 employees), the industry is dominated by several large firms; with the four largest accounting for 30% of its shipments. Many of the companies reporting in SIC 291 are also major petrochemical producers. Information about their activities are reported separately under SIC classification 28. The dominant production cost is materials (82%), which are composed primarily of crude oil. The U.S. petroleum refining industry has not maintained a favorable balance of trade. Oil import and export data show that although the value of oil exports have risen 13 fold in the past ten years, compared with a seven fold increase for oil imports

TABLE 8-4

BUSINESS PROFILE OF THE PETROLEUM REFINING INDUSTRY (SIC 291)

	1972	1977	1979	1981	1983	1984 EST.
SHIPMENTS (BILLION $)						
CURRENT $	25.9	91.7	140.4	215.6	171.8	—
1972 $	25.9	32.7	35.1	30.3	28.6	30.3
BARRELS SHIPPED (BILLIONS)	4.8	5.7	5.7	5.1	4.9	5.1
TOTAL EMPLOYMENT (THOUSANDS)	100.8	102.5	108.3	108.8	100.6	—



Source: Published BLS Data

VALUE OF PLANT, 1976, BILLION $, CURRENT 22.3

	1972	1981	1983
NEW CAPITAL EXPENDITURES, BILLION $			
CURRENT $	1.1	4.9	—
1972 $	1.1	0.8	—
REFINERY CAPACITY, %	94.1	73.9	76.1

SOURCES: U.S. DOC/BIE: 1984 U.S. INDUSTRIAL OUTLOOK
U.S. DOC/BOC: CENSUS OF MANUFACTURES, 1977
U.S. DOL/BLS
U.S. DOE/EIA

TABLE 8-5

STRUCTURAL PROFILE OF THE PETROLEUM REFINING INDUSTRY (SIC 291)

ESTABLISHMENTS (1977) (CATEGORIZED BY NUMBER OF EMPLOYEES)	
SMALL (<20)	69
INTERMEDIATE (20-1000)	261
LARGE (>1000)	19
TOTAL	349

LEADING FIRMS

NAME	REFINERY RUNS (THOUSAND BBL/DAY)
EXXON CORP.	3300
TEXACO INC.	2000
MOBIL CORP.	1600
GULF CORP.	900
STD. OIL CALIF. (CHEVRON)	900
STD. OIL INDIANA (AMOCO)	900
SHELL OIL	800
ATLANTIC RICHFIELD (ARCO)	700
PHILLIPS PETROLEUM	500
SUN COMPANY (SUNOCO)	500
TOTAL	12,100
% OF INDUSTRY	81

	MFG. LABOR	OTHER LABOR	MATERIALS	ENERGY	CAPITAL
PRODUCTION COST DISTRIBUTION, 1977	1.5%	0.8%	82.4%	2.5%	12.8%

R&D EXPENDITURES 1972 $, MILLION	1970	1974	1977	1979
	563	541	657	752

AVERAGE ANNUAL COST OF POLLUTION CONTROL (MILLIONS 1972 $)	1970-78	1981-90
AIR	7	28
WATER	62	145

	1972	1977	1979	1981	1982
REFINED OIL EXPORTS, MILLION CURRENT $	441	1,054	1,700	3,393	5,957
REFINED OIL IMPORTS, MILLION CURRENT $	2,101	8,728	11,054	15,766	15,590

SOURCES: U.S. DOC/BIE: 1984 U.S. INDUSTRIAL OUTLOOK
U.S. DOC/BOC: CENSUS OF MANUFACTURES, 1977
VALUE-LINE INVESTMENT SURVEY, 1984
NATIONAL SCIENCE BOARD: NATIONAL SCIENCE INDICATORS
EPA: 1984 COST OF CLEAN AIR AND WATER REPORT TO CONGRESS

during the same period, oil imports still exceed oil exports by nearly three times. Although consumption of petroleum has fallen in recent years (5.6 billion barrels in 1982 compared to 5.9 billion barrels in 1981 and 6.8 billion barrels in 1979) due to a slowdown in the U.S. economy, decreased usage coupled with increased fuel efficiency of the nation's automobile fleet, and sharp increases in oil prices in recent years, petroleum demand still exceeds domestic production; currently 25% of the nation's crude oil is imported. R&D expenditures, expressed in constant 1972 dollars, have been steadily increasing, rising from $563 million in 1970 to $752 million in 1979.

Table 8-6 outlines the constraints present in the petroleum refining industry. The industry is affected by government regulations mandating the type of fuel to be produced (i.e., low lead and unleaded fuels). The industry's labor force is highly unionized, 2-year contracts are generally in force. Fiscal/monetary policy affects the refining industry because the industry is highly capital intensive.

TABLE 8-6

CONSTRAINT PROFILE OF THE PETROLEUM REFINING INDUSTRY (SIC 291)

GOVERNMENT REGULATIONS	EPA REGULATIONS REQUIRE LOW SULFUR, LOW-LEAD PRODUCTS, AS WELL AS THE REDUCTION OF NOXIOUS WASTES.
LABOR RELATIONS	HIGH DEGREE OF UNIONIZATION; 90% OF EMPLOYEES COVERED BY COLLECTIVE BARGAINING AGREEMENTS.
FISCAL/MONETARY POLICY	REFINING INDUSTRY IS HIGHLY CAPITAL INTENSIVE. CAPITAL OUTLAYS/PRODUCTION WORKER ROSE SEVENFOLD FROM 1960 TO 1975 AND TREND IS CONTINUING. AFFECTED BY COST AND AVAILABILITY OF MONEY

SOURCE: U.S DOL/BLS

Role of Technologies in Long-Term Strategic Outlook

The petroleum refining segment has been impacted by several major developments in the past few years that will result in permanent changes. These include

- Removal of TEL as an octane enhancer in gasoline;
- More efficient utilization of fuels;
- Changes in relative product demands;
- Decline in availability of light, sweet crudes; and
- Environmental regulations.

The removal of lead from gasoline has forced refiners to find other methods for meeting octane requirements. These include more catalytic reforming capacity and use of alcohols and blends of other oxygenated hydrocarbons. The national program of energy conservation has reduced the demand for the products produced by this industry. The result of this being a redundancy in refining capacity in the U.S.; the solution, which is currently under way, is the rationalization of capacity (i.e, the reduction of over-capacity). The composition of the demand barrel in the U.S. has been getting lighter (i.e., more distillate, less residual fuel); a trend that is expected to continue in the future. This has fairly significant implications on future processing capabilities of refineries, particularly as crude quality is also declining. Finally, environmental regulations will be a major consideration. This must be factored into future developments by this industry.

In the long term, the future acquisition of feedstocks will become a major problem area for the refining industry. Alternative sources of raw materials such as syncrude from oil shales and tar sands will be developed. This, in turn, will create new processing problems for the refining industry due to the unusual character of these new feedstocks, namely, high nitrogen, viscosity, and metals including arsenic. To quote George Masologites of Arco R&D ".... historically, the petroleum and allied industries have moved forward aggressively with technology."

Table 8-7 summarizes the technologies currently being developed and planned. In the near-term, petroleum refining companies will be concentrating on optimizing the processing configuration of their refineries to increase profitability. This will involve development and application of various types of conversion processes which basically rearrange the natural molecular configurations in petroleum into altered forms that are more suitable for refined fuel products. In particular, technologies for conversion of petroleum residues (atmospheric and vacuum bottoms) will have high priority. Peripheral technologies that could also see application in this timeframe include fluid bed combustion, computerized process controls and fuel cells.

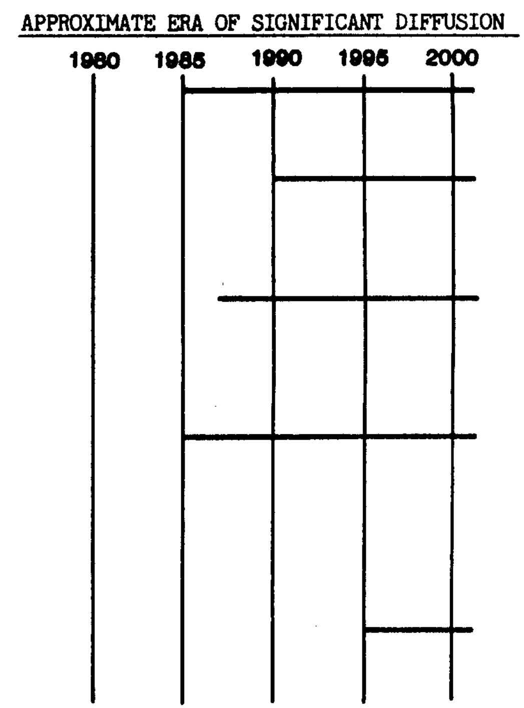
An important element of refinery process technology innovation is catalyst development. Future efforts in this area will be aimed at formulating specialized catalysts which will have unique abilities to solve such problems as refining high metal content residuals, high-nitrogen or high-sulfur gas oils, or to resist attrition in fluid crackers.

The major long-term concern to the petroleum refining industry is securing a reliable supply of liquid hydrocarbons to transform into fuels. While exploration and production activities in the petroleum industry are classified elsewhere, this issue does have significant impact on the petroleum product sector. Eventually, oil producing and refining companies will have to turn to unconventional oil resources for future refinery feedstocks. The sources of unconventional oil in order of likely commercialization include:

TABLE 8-7

NEW PETROLEUM REFINING TECHNOLOGIES

TECHNOLOGY	DESCRIPTION
COMPUTER CONTROL	MONITOR AND/OR CONTROL REFINING PROCESSES
CATALYST DEVELOPMENT	SPECIALIZED CATALYSTS TO SOLVE REFINING TECHNIQUES
ENERGY CONSERVATION METHODS	USE OF HEAT EXCHANGERS, FURNACE AIR PREHEATERS, WASTE-HEAT STEAM GENERATORS
PREVENTIVE MAINTENANCE TECHNOLOGIES	ULTRASONIC TESTING, X-RAY TESTING, INFRARED CAMERAS, MAGNETIC PARTICLE TESTING, AND CORROSION PROBES TO DETERMINE EQUIPMENT RELIABILITY
MULTI-FUEL CAPACITY PLANTS	USE OF UNCONVENTIONAL FUELS



SOURCES: U.S. DOL/BLS

- heavy crudes (Lloydminster, Oronoco, Oxnard);

- tar sands and shale (syncrudes); and

- coal.

Heavy crudes have high viscosity at formation conditions and require some type of thermal stimulation to extract them from the ground. Various techniques are being investigated, including steam drive, fire-flood, downhole steam generation, microwave heating, etc. More development is needed to perfect these technologies and achieve lower production costs.

Similarly, several hot water and solvent processes for tar sands extraction and retorting technologies for shale are being tested and scaled up to commercial size modules. The syncrudes produced from these sources would be processed in existing refineries, albeit with modifications to handle the high nitrogen, oxygen, and metals content.

The largest hydrocarbon resource in the U.S. is coal. In its natural form it is not suitable for many petroleum fuel end-uses. Finding an efficient and cost-effective process for converting coal to transportable liquid fuels is one of the critical long-term needs for the nation. The Sasol complex in South Africa where coal is converted to liquid fuels via Fischer-Tropsch technology is a commercial scale facility. While this indirect approach to coal liquefaction is technically feasible, the basic process was developed in the 1940s. Research is going on to improve the process efficiency and selectivity of the Fischer-Tropsch process. Research into direct hydrogenation of coal is an area which also holds promise for obtaining useable liquid fuels from coal. Current interest is focused on two-stage liquefaction which involves extraction followed by hydrogenation and appears to reduce hydrogen consumption while not adversely affecting liquid yields.

Conclusion

Any national industrial technology policy must inevitably involve the petroleum refining industry. As the largest consumer of fossil energy in the world, it is essential that the U.S. continue to invest in new techniques for extraction and refining of liquid hydrocarbons. The track record of the petroleum industry is quite good with respect to responding to such challenges. However, as readily available sources of hydrocarbons decline, the cost of developing new technologies is climbing exponentially. In development areas like oil shale and coal conversion, commercial scale demonstration modules can cost hundreds of millions of dollars. Because of the high risk and financial impact of failure, oil companies need some means of shifting development costs. Some form of national initiative which was less concerned with near-term commercial viability would be welcomed by the petroleum industry.

B.9 "PRINTING AND PUBLISHING" (SIC 27)

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SOURCES: EOP/OMB:

Standard Industrial Classification Manual, 1972

U.S. DOC/BOC:

Statistical Abstract of the U.S., 1982-1983

Census of Manufactures, 1977

Annual Survey of Manufactures, 1981

U.S. DOC/BIE:

U.S. Industrial Outlook, 1984

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SOURCES (CONT.):

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B.9 "PRINTING AND PUBLISHING" (SIC 27)

The printing and publishing subsector, SIC 27, is the ninth largest manufacturing subsector. Its value added accounted for 5.7% of the manufacturing sector's contribution to GDP in 1980. The subsector's chief characteristics are as follows:

- A high degree of framentation, out of a total of approximately 49,000 establishments, 40,000 employed less than 20 persons (1977).

- A labor productivity of $19,695 per employee year or $10.26 per employee hour (1980, 1972 $), ranking this subsector thirteenth among the nation's 20 manufacturing subsectors. A compound annual labor productivity growth rate average of 0.4%/year from 1972 to 1980 ranks this subsector seventeenth. The labor productivity for the comparable Japanese subsector was $13,845 per employee year or $7.21 per employee hour (1980, 1972 $), ranking this subsector sixth among Japan's 20 manufacturing subsectors. The compound annual labor productivity growth rate for the Japanese subsector averaged 5.5%/year from 1972 to 1980, ranking this subsector fifth.

- A lower than average capital investment base relative to other subsectors within the manufacturing sector. Capital investment amounted to $9,326 in total assets per worker, ranking sixteenth in terms of (depreciated) fixed assets (1980, 1972 $). New yearly capital expenditures were $1,228 per employee (1980, 1972 $), ranking fifteenth in the manufacturing sector. Total capital productivity, measured as dollars of added value output per dollar of capital investment, was 1.14 (1981).

- No R&D activities. However, industry suppliers advance the technology used through anticipation of future user needs.

- Imports and exports are generally not significant; in 1983, they were only 0.3% and 0.07% of receipts.

Table 9-1 shows the major products produced by the subdivisions of the subsector and their contribution to the subsector's share of the GDP. Table 9-2 summarizes the principal economic characteristics of the subsector.

Two subdivisions--Newspaper Publishing and Printing (SIC 271) and Commercial Printing (275)--accounted for approximately 56% of the subsector's contribution to manufacturing in 1980. These two subdivisions of the printing and publishing subsector have been selected for detailed analysis in order to assess long-term technology needs.

B.9.1 NEWSPAPER PUBLISHING AND PRINTING (SIC 271)

The major products of this subdivision are daily, Sunday, and weekly newspapers. In general, the companies involved in this industry have been leaders in adopting new technology to reduce costs, primarily through the reduction of labor.

The business and structural profiles of the newspaper subdivision are summarized in Tables 9-3 and 9-4, respectively. The value of receipts/production worker increased from $48,700 in 1972 to $64,917 in 1982 (1972 $). This was due both to the increased value of receipts and a reduction in the number of production workers. Receipts are expected to increase by 3.0% in 1984. The 16% increase in total employment from 1972 to 1983 was due primarily to an increase in editorial staff.

New capital expenditures were approximately $1 billion in 1981; however, this represented only 13.2% of total assets.

TABLE 9-1

CLASSIFICATION OF MAJOR PRODUCTS OF THE PRINTING AND PUBLISHING INDUSTRY (SIC 27) AND CONTRIBUTION TO THE SUBSECTOR IN 1980

SIC CODE	SUBDIVISION DESIGNATION AND TYPICAL PRODUCTS	% CONTRIBUTION
271	**NEWSPAPERS: PUBLISHING AND PRINTING**	28.9
	NEWSPAPERS.	
275	**COMMERCIAL PRINTING**	26.8
	BREAD WRAPPERS, LABELS, CALENDARS, PLAYING CARDS, POSTERS, POSTCARDS, STATIONERY, AND CONTRACT-PRODUCED PRINTED MATERIAL OF ALL TYPES.	
272	**PERIODICALS: PUBLISHING AND PRINTING**	12.6
	COMIC BOOKS, MAGAZINES, AND TRADE JOURNALS.	
273	**BOOKS**	12.4
	BOOKS AND PAMPHLETS.	
276	**MANIFOLD BUSINESS FORMS**	4.9
	SALESBOOKS AND OTHER BUSINESS FORMS.	
279	**PRINTING TRADE SERVICES**	4.1
	TYPESET COMPOSITION, PHOTO-ENGRAVING PLATES, ELECTROTYPE PLATES, AND LITHOGRAPHIC PLATES.	
274	**MISCELLANEOUS PUBLISHING**	4.0
	ATLASES, GLOBE COVERS, MAPS, GUIDES, PATTERNS, AND RACETRACK PROGRAMS.	
278	**BLANKBOOK AND BOOKBINDING**	4.0
	ACCOUNT BOOKS, LOOSELEAF BINDERS, DIARIES, RECORD ALBUMS, AND CHECKBOOKS.	
277	**GREETING CARD PUBLISHING**	2.3
	GREETING CARDS.	

SOURCES: U.S. DOC/BOC: STATISTICAL ABSTRACT OF THE U.S., 1982-3
EOP/OMB: STANDARD INDUSTRIAL CLASSIFICATION MANUAL, 1972

TABLE 9-2

SUBDIVISIONS AND CHARACTERIZATION OF THE PRINTING AND PUBLISHING INDUSTRY (SIC 27) DURING 1980, IN 1972 DOLLARS

SUBDIVISION	PERCENTAGE CONTRIBUTION	NUMBER OF EMPLOYEES (1,000)	NUMBER OF ESTABLISHMENTS[a] TOTAL	NUMBER OF ESTABLISHMENTS[a] LESS THAN 20 EMPLOYEES	NUMBER OF ESTABLISHMENTS[a] 100 OR MORE EMPLOYEES	GROSS VALUE OF FIXED ASSETS ($/EMPLOYEE)	NEW CAPITAL EXPENDITURES ($/EMPLOYEE)	LABOR PRODUCTIVITY ($/EMPLOYEE)
ALL PRINTING & PUBLISHING (27)	100	1,262.8	49,767	40,623	1,909	9,326	1,228	19,695
NEWSPAPER (271)	30	414.0	8,867	6,718	610	9,814	1,283	17,342
PERIODICALS (272)	12	77.8	2,994	2,464	105	7,100	955	40,341
BOOKS (273)	13	112.6	2,694	1,977	201	9,219	1,099	27,351
MISC. PUBLISHING (274)	4	47.4	2,352	2,016	66	5,315	694	21,200
COMMERICAL PRINT-ING (275)	27	414.6	26,815	23,177	571	10,150	1,238	16,088
MANIFOLD BUSINESS FORMS (276)	5	49.2	795	317	130	13,959	1,915	24,876
GREETING CARD PUBL-SHING (277)	2	21.1	166	113	30	8,681	1,358	26,953
BLANKBOOKS AND BOOKBINDING (278)	3	67.2	1,492	916	141	5,502	818	14,683
PRINTING TRADE SERVICES (279)	4	58.9	3,592	2,925	55	7,195	1,410	17,301

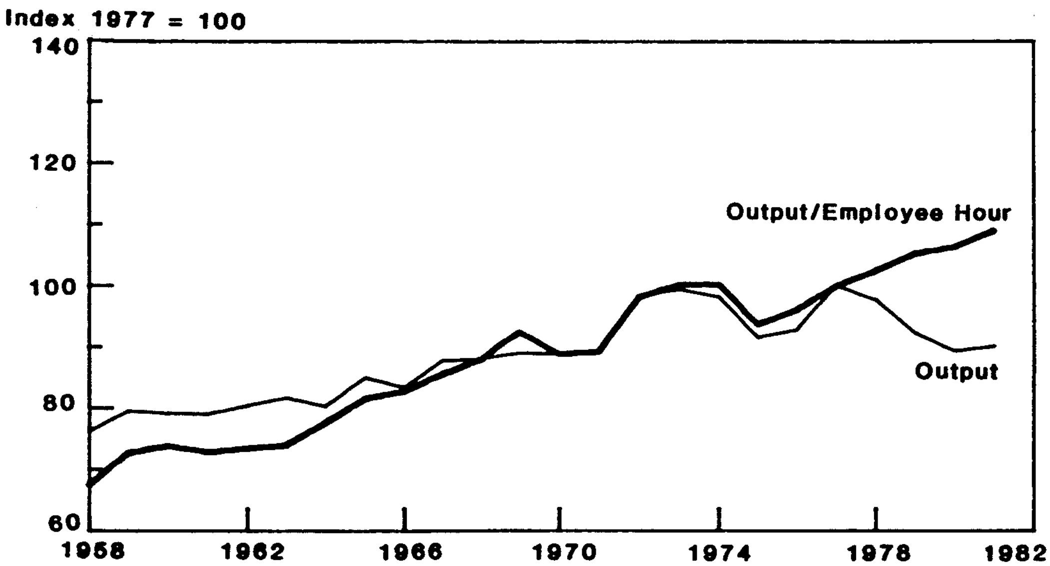
[a] 1977

SOURCE: U.S. DOC/BOC: CENSUS OF MANUFACTURES, 1977; ANNUAL OF SURVEY OF MANUFACTURES, 1981

TABLE 9-3

BUSINESS PROFILE OF
NEWSPAPER PUBLISHING AND PRINTING (SIC 271)

RECEIPTS (BILLION $)	1972	1977	1979	1981	1983	ANNUAL RATE OF GROWTH 1972-82
CURRENT $	8.3	13.1	16.2	20.0	24.2	10.3
1972 $	8.3	8.4	8.9	9.2	9.6	1.4
TOTAL EMPLOYMENT (THOUSANDS)	348.5	349.9	396.2	419.0	414.7	



Source: Unpublished BLS Data

VALUE OF PLANT, 1976, CURRENT $, BILLION — 4.5

OPERATING CAPACITY, 1983, % — 87

NEW CAPITAL EXPENDITURES	1977	1981
CURRENT $, BILLION	0.5	1.0
% OF TOTAL ASSETS		13.2

ADVERTISEMENTS, 1983

% OF TOTAL REVENUES	80
BREAKDOWN, % OF TOTAL VOLUME	
RETAIL	55 TO 60
CLASSIFIED	25 TO 30
NATIONAL	10 TO 15

SOURCES: U.S. DOC/BOC: CENSUS OF MANUFACTURES, 1977
U.S. DOC/BIE: 1984 U.S. INDUSTRIAL OUTLOOK
U.S. DOL/BLS: 1984 VALUE-LINE INVESTMENT SURVEY
ARTHUR D. LITTLE, INCORPORATED

TABLE 9-4

STRUCTURAL PROFILE OF
NEWSPAPER PUBLISHING AND PRINTING (SIC 271)

ESTABLISHMENTS (1977)
(CATEGORIZED BY NO. OF EMPLOYEES)

SMALL (<20)	6,718
INTERMEDIATE (20-1000)	2,093
LARGE (>1000)	56
TOTAL	8,867

(7,386 COMPANIES)

LEADING FIRMS (1983)

NAME	DOMESTICALLY GENERATED SALES ($ MILLION)
KNIGHT-RIDDER	1400
GANNETT CO.	1329
TIMES MIRROR	1196
DOW JONES	814
NEW YORK TIMES	786

PRODUCTION COST DISTRIBUTION

	MFG. LABOR	OTHER LABOR	MATERIALS	ENERGY	CAPITAL
1977	14%	19%	26%	1%	40%
1980	36.7%	22.6%	33.8%	0.9%	6%

CIRCULATION STRUCTURE

	1965	1983
DAILYS (1710 NEWSPAPERS)		
CIRCULATION, MILLION COPIES	60.3	63.0
MORNING EDITIONS		
NUMBER	320.0	440.0
CIRCULATION, MILLION COPIES	24.0	34.0
EVENING EDITIONS		
NUMBER	1444.0	1300.0
CIRCULATION, MILLION COPIES	36.3	29.0
WEEKLYS (7626 NEWSPAPERS)		
CIRCULATION, MILLION COPIES	25.0	44.3
SUNDAY EDITIONS		
NUMBER	562.0	770.0
CIRCULATION, MILLION COPIES	46.4	57.0

SOURCES: U.S. DOC/BOC: CENSUS OF MANUFACTURES, 1977
VALUE-LINE INVESTMENT SURVEY, 1984
ARTHUR D. LITTLE, INCORPORATED

On average, 80% of U.S. newspaper receipts comes from the sale of advertising. Gains in overall U.S. economic activity in 1983 were reflected by surges in classified advertising (20% over 1982) and retail ads (10 to 12% over 1982). National accounts recorded only a 5 to 7% increase in advertising revenues in 1983. Decreased ad expenditures by some automobile and cigarette companies, attributed in part to increases in newspaper advertising rates, accounted for the only nominal gains in national accounts.

As illustrated in Table 9-4, approximately 76% of establishments employ 20 persons or less. While the top 20 firms accounted for $10.4 billion in sales, the top 5 firms were responsible for 50% of this amount. The subdivision is fairly labor intensive, employing many writers, editors and researchers. Correspondingly, wages accounted for 33.8% of production costs in 1977. This increased to 59.3% of costs in 1980. Materials, primarily paper and paperboard mill products, increased from 26% of production costs in 1977 to 34% of costs in 1980.

Significant structural changes have occurred in the industry during the past two decades. The number of papers, both daily and weekly have declined. Changes in consumer preferences and tastes in daily newspapers are reflected in the continued decline of evening papers and the increased circulation of morning and Sunday papers (Table 9-4).

Among the institutional constraints which affect the subdivision, three are primary as shown in Table 9-5. Labor intensive distribution functions limit circulation expansion. All automation ceases after loading. Circulation relys on localized forms of transportation and a system of hand-delivery carriers. This type of distribution operation seriously curtails the speed at which delivery occurs.

TABLE 9-5

DOMINANT CONSTRAINTS AFFECTING
NEWSPAPER PUBLISHING AND PRINTING (SIC 271)

DISTRIBUTION FUNCTIONS	LABOR INTENSIVE DISTRIBUTION, CONSISTING PRIMARILY OF LOCALIZED TRANSPORTATION METHODS AND HAND-DELIVERY.
LABOR RELATIONS	PRECEDENTS EXIST FOR LABOR STRIKES WHICH CAN EFFECTIVELY PARALYZE PRODUCTION. LARGE UNION PRESENCES WITH PREDICTED MERGERS WITH THE TEAMSTERS UNION.
MATERIAL LIMITATIONS	HIGH PEAK COST FOR NEWSPRINT. NEWSPAPERS ARE LIMITED TO THIS MATERIAL FOR PRINTING.

SOURCE: U.S. DOC/BIE: 1984 U.S. INDUSTRIAL OUTLOOK

TABLE 9-6

TIMELY INFORMATION DELIVERY

INFORMATION SOURCE	PUBLISHER TO CONSUMER	ABILITY OF CONSUMER TO SELECT INFORMATION NEEDED	DEPTH OF INFORMATION SUPPLIED
TV	SECONDS	LOW	LOW
CABLE TV	SECONDS	HIGH	MEDIUM & GROWING
NEWSPAPER	HOURS	HIGH	MEDIUM
WEEKLY NEWS MAGAZINE	DAYS	HIGH	MEDIUM +
MONTHLY GENERAL OR SPECIAL INTEREST MAGAZINE	WEEKS	HIGH	HIGH

SOURCE: ARTHUR D. LITTLE, INCORPORATED

Labor relations also constrain the industry. Because of the labor intensive nature of production and delivery methods, labor strikes can slowdown or halt production. A strong union network is present in the form of the International Typographical Union (ITU) and the Newspaper Guild. A more aggressive workforce could result from merger overtures made to the members of the ITU by the Teamsters Union. Entrance of the Teamsters into the newspaper industry's labor negotiations could present management with more intense labor problems.

The industry is also curtailed in the use and costs of materials. During the recent economic recession, the price of newsprint produced in American and Canadian mills reached an all time high of $500/metric ton. Efforts to substantially reduce this cost have failed. Also, the high cost of materials used in producing the consumer-preferred color photography will continue to drive up material costs.

Competitive Issues Affecting Newspaper Publishing and Printing

The newspaper industry tends to suffer more from domestic competition than from foreign imports. Although circulation continues to rise, it is not keeping pace with population increases. Competition from other media sources, such as mail delivery, television, radio, and cable television continues to increase. As shown in Table 9-6, the consumer receives the information hours after publishing, with a high selective capability and information content of a medium depth. While this format may compete with magazines which have a lag-time of several days to several weeks or with commercial television which has a very low selective capability, it may not be able to compete effectively with cable television with high selectivity, information of a medium to high-depth and a much shorter lag-time.

Material costs and the high cost of labor continue to drive up the cost of a single newspaper copy. Revenues from subscriptions and single copy sales represent about 20% of total receipts. By 1983, more than 80% of U.S. daily papers were priced at 25 cents per copy, up from 10 cents in 1970 and 15 cents in 1975.

As a result of increased domestic media competition and high material and labor costs, many publishers are diversifying into new forms of print and broadcast advertising. Cable television provides both a format for the introduction of personalized information, such as databases, as well as highly selective audiences to be advantageously reached by advertisers. Newspaper publishers are becoming increasingly active in cable television ventures, recognizing opportunities for marketing interactive databases and researching the possible conversion of some advertising from print to broadcast media.

Productivity in Newspaper Publishing and Printing

Productivity in the newspaper industry is, by its very nature, difficult to both define and measure. The industry is comprised of two very different processes: publishing and printing. The publishing process is largely a mental one. The editors and journalists choose subjects, investigate them and commit subsequent thoughts to paper or computer memory. These thoughts are then edited and printed. For nearly all newspapers, the printing process is completely automated through the use of phototypesetting and web-offset printing, both of which are highly compatible with computer-aided editing, typesetting and word processing. This technology was largely diffused throughout the industry by 1978, so it is reasonable to assume that this major productivity enhancing technology is in place where economy-of-scale makes it cost effective.

Difficulty arises if attempts are made to measure productivity in terms of dollars of value added per employee, as this value includes both the mechanical and editorial processes. To some extent, there are economies-of-scale to be realized during the printing process, but these are offset by the amounts of time necessary to produce the editorial content. As shown in Table 9-7, newspapers employing between 50 and 100 people experienced the largest gain in productivity during 1972 and 1977. However, this was also in part, because their editorial staff employment went up nearly 12%.

Table 9-8 shows that small and large newspapers have essentially the same physical productivity in the publishing area. However, they differ significantly in both the printing and product distribution areas. This is because the small newspaper has a circulation of approximately 29,000 while the large newspaper circulates about 260,000 papers. However, once the publishing function is accomplished, either the small or large newspaper could print more or less product with little additional printing labor cost.

Major Elements of the Production Process

Figure 9-1 shows a breakdown of the major cost elements for two model newspapers. The larger newspaper is most sensitive to material cost while the smaller newspaper is most sensitive to publication labor costs. In both cases, printing labor is relatively insensitive.

The cost of a single published page is relatively high. However, once the publication function is accomplished, the original page can be printed in large multiples (as in the case for the larger newspaper) and the cost of the newspaper will fall. Naturally, as the larger newspaper prints more copies, material costs will rise.

Role of Technology in Long-term Strategic Outlook

The limited revenues of newspaper establishments preclude extensive research and development activities. However, industry

TABLE 9-7

PRODUCTIVITY DATA FOR NEWSPAPER PUBLISHING AND PRINTING (SIC 271)

AVERAGE EMPLOYEES/ ESTABLISHMENT	PRODUCTIVITY (VALUE ADDED/EMPLOYEE, CURRENT $) 1972	1977	CHANGE IN PRODUCTIVITY (%)	EMPLOYMENT (THOUSANDS) 1972	1977	CHANGE IN EMPLOYMENT %
1-4	15,686	28,594	82.3	6.7	6.9	3.0
5-9	13,166	23,039	75.0	9.6	7.6	-20.8
10-19	12,361	18,585	50.4	13.3	15.2	14.3
20-49	12,149	19,473	60.3	32.9	31.7	-3.6
50-99	9,142	22,673	148.0	32.8	36.7	11.9
100-249	17,793	25,970	46.0	51.2	52.8	3.1
250-499	18,541	26,790	44.5	46.3	46.3	0.0
500-999	12,553	30.019	139.1	45.5	47.1	3.5
1000-2499	36,797	32,180	-12.5	69.6	68.7	-1.3
2500+	22,241	31,851	43.2	41.0	37.0	-9.7
TOTAL	**17,843**	**27,205**	**52.5**	**348.9**	**349.9**	**0.29**

SOURCE: ARTHUR D. LITTLE, INCORPORATED

TABLE 9-8

PHYSICAL PRODUCTIVITY FOR MODEL NEWSPAPERS

ITEM	SMALL URBAN NEWSPAPER	LARGE METROPOLITAN NEWSPAPER
PUBLISHED PAGES/MAN YEAR	134	135
MILLION PRINTED PAGES/MAN YEAR	34	160
MILLION DELIVERED PAGES/MAN YEAR	19	96

SOURCE: ARTHUR D. LITTLE, INCORPORATED

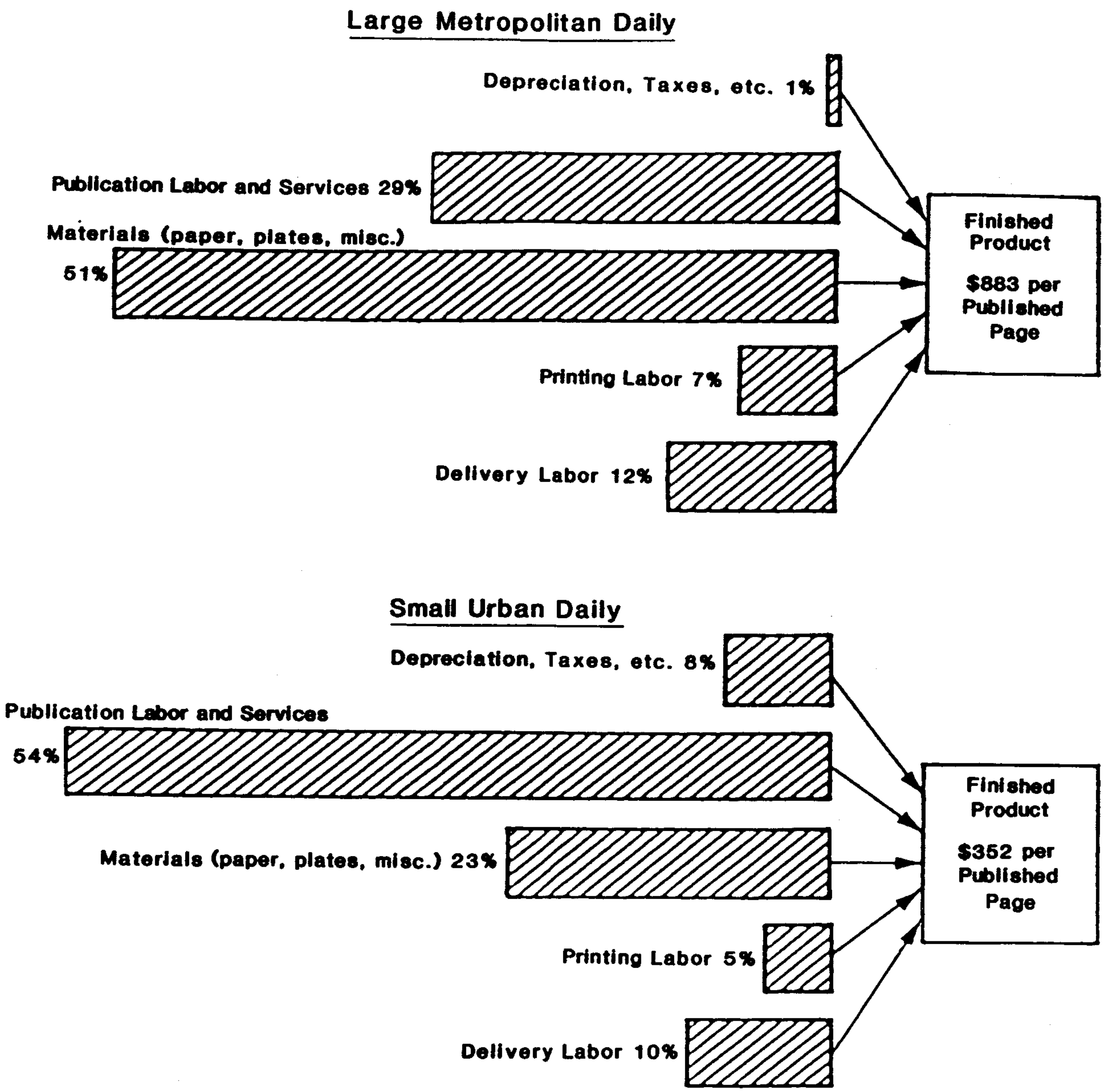


Figure 9-1. Major Cost Elements for Newspaper

suppliers are well aware of its large market potential and exert considerable time and money to advance the technology used by the industry. Moreover, in recent years industry expenditures have frequently been in anticipation of customer needs rather than in response to them; i.e., technology from outside the industry has stimulated change. It is expected that this situation will continue.

The technology of a printing process or printed product can be divided into the following three major technological areas.

- **Prepress**--those technologies that assemble information on a printing plate.

- **Printing**--the mechanical process that prints (reproduces) multiple copies of the plate image, and

- **Product Assembly**--the mechanical process that constructs the newspaper, magazine, book, etc.

Table 9-9 outlines the technologies currently being adopted in newspaper publishing and printing. Traditionally, newspapers were produced by a mechanical process, "paste up," that was highly labor intensive. In the last two decades, photomechanical prepress systems have begun to erode the role of labor in large newspapers. More recently electronic prepress systems have impacted the traditional time and labor constraints of large and small newspapers. Today a press-ready printing plate can be assembled and prepared directly from a computer. The overall result of this electronic information handling technology is to vastly reduce labor and to increase the capability to deliver world wide news and advertising in a small fraction of the time required 10 or 20 years ago.

For example, Table 9-10 illustrates how these current technologies can affect the operating costs of a large city newspa-

TABLE 9-9

PRINCIPAL SHORT AND MEDIUM TERM TECHNOLOGIES ENTERING NEWSPAPER PUBLISHING AND PRINTING (SIC 271)

TECHNOLOGY	DESCRIPTION	PRINCIPAL IMPACT
ELECTRONIC COMPOSITION		
• TYPESETTING COMPUTERS	AUTOMATICALLY PERFORMS TYPESETTING TASKS.	INCREASED LABOR PRODUCTIVITY
• VIDEO DISPLAY TERMINALS	ALLOWS CONTROL OVER ENTERING, CORRECTING, AND EDITING COPY BEFORE TYPESETTING.	INCREASED LABOR PRODUCTIVITY
• PHOTOTYPESETTING	SETS TYPE ON FILM OR PHOTOSENSITIVE PAPER OFFERS FLEXIBILITY IN CHANGING TYPE STYLES AND SIZES.	INCREASED PRODUCT FLEXIBILITY AND QUALITY
DATA TRANSMISSION	TRANSMISSION OF MEDIA THROUGH MICROWAVE STATIONS AND COMMUNICATION SATELLITES CAN ACCOMMODATE AUTOMATIC SCANNING AND PLATE-MAKING EQUIPMENT.	INCREASED LABOR PRODUCTIVITY
SCANNERS		
• OPTICAL CHARACTER RECOGNITION SCANNERS FOR TYPESETTING	SENSES TYPEWRITTEN MATERIAL AND CONVERTS THE INFORMATION INTO DIGITAL SIGNALS.	INCREASED LABOR PRODUCTIVITY
• ELECTRONIC SCANNERS	ELECTRONIC BREAKDOWN OF THE COLORS IN A PHOTOGRAPH RESULTING IN A SET OF PRINTING PLATES.	INCREASED PRODUCT QUALITY
WEB-OFFSET PRINTING	PHOTOGRAPHICALLY PROCESSED LIGHTWEIGHT PRINTING PLATES PRINTING ON A CONTINUOUS ROLL OF PAPER.	INCREASED PRINTING PRODUCTIVITY
BINDING OPERATIONS	TECHNOLOGICAL IMPROVEMENTS THAT COMBINE SEPARATE BINDING OPERATIONS AND AUTOMATIC CONTROLS.	INCREASED PRINTING PRODUCTIVITY
NEWSPAPER MAILROOM	AUTOMATIC BUNDLE-TYPING; COUNTERSTACKING, AND SUPPLEMENT INSERTION MACHINES, AND INCORPORATION OF MICROCOMPUTER TO MAILROOM AND DISPATCH OPERATIONS.	DECREASE IN BINDING TIME

APPROXIMATE ERA OF SIGNIFICANT DIFFUSION

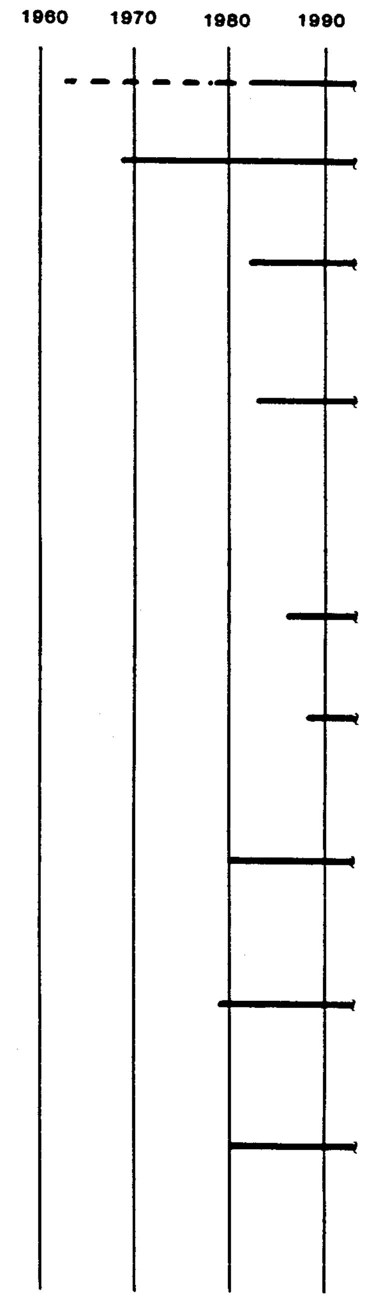


TABLE 9-10

COMPARATIVE TECHNOLOGY OPERATING COSTS

OPERATING COSTS	USING TRADITIONAL TECHNOLOGY (1972 VINTAGE) $/YEAR (000)	USING TRADITIONAL TECHNOLOGY (1972 VINTAGE) $/PUBLISHED PAGE	USING CURRENT TECHNOLOGY (1972 $) $/YEAR (000)	USING CURRENT TECHNOLOGY (1972 $) $/PUBLISHED PAGE
NEWS-EDITORIAL	5,253.6	137.94	5,428.5	142.53
ADVERTISING	2,745.5	72.09	3,066.7	80.52
COMPOSITION	5,580.9	146.53	1,793.1	47.08
ENGRAVING/CAMERA	339.8	8.92	405.6	10.65
STEREOTYPING/ PLATEMAKING	1,036.3	27.21	1,601.3	42.04
PRESSROOM	2,214.0	58.13	2,327.4	61.11
CIRCULATION/ DISTRIBUTION	3,944.0	103.56	3,944.0	103.56
NEWSPRINT	16,181.3	424.86	15,048.4	395.12
TOTAL OPERATING COSTS	37,321.0	979.91	33,615.0	882.61

SOURCE: ARTHUR D. LITTLE, INCORPORATED

per, with a total circulation of 260,000. The data indicate that almost $4 million/year in operating costs can be saved at an estimated investment of about $2.5 million.

Electronic technologies have essentially eliminated the original printing process and given birth to new processes. Offset printing thus predominates in newspaper production systems today, because offset plates are very compatible with electronic prepress systems, particularly those with laser output. However, direct letterpress and flexographic photopolymer plates (a rubber letter press type), are economically efficient because they can be linked to electronic prepress systems via conventional photographic technology.

While the electronic revolution has changed prepress operations, the printing operation itself is still largely an automated mechanical process, controlled by the high-speed dynamics of converting a roll of newsprint into a finished newspaper.

Unfortunately, automation and mechanical techniques end when the newspapers are finally loaded on a truck by a computerized conveyor system. Local transportation and hand delivery become the operative factors at this point.

B.9.2 COMMERCIAL PRINTING (SIC 275)

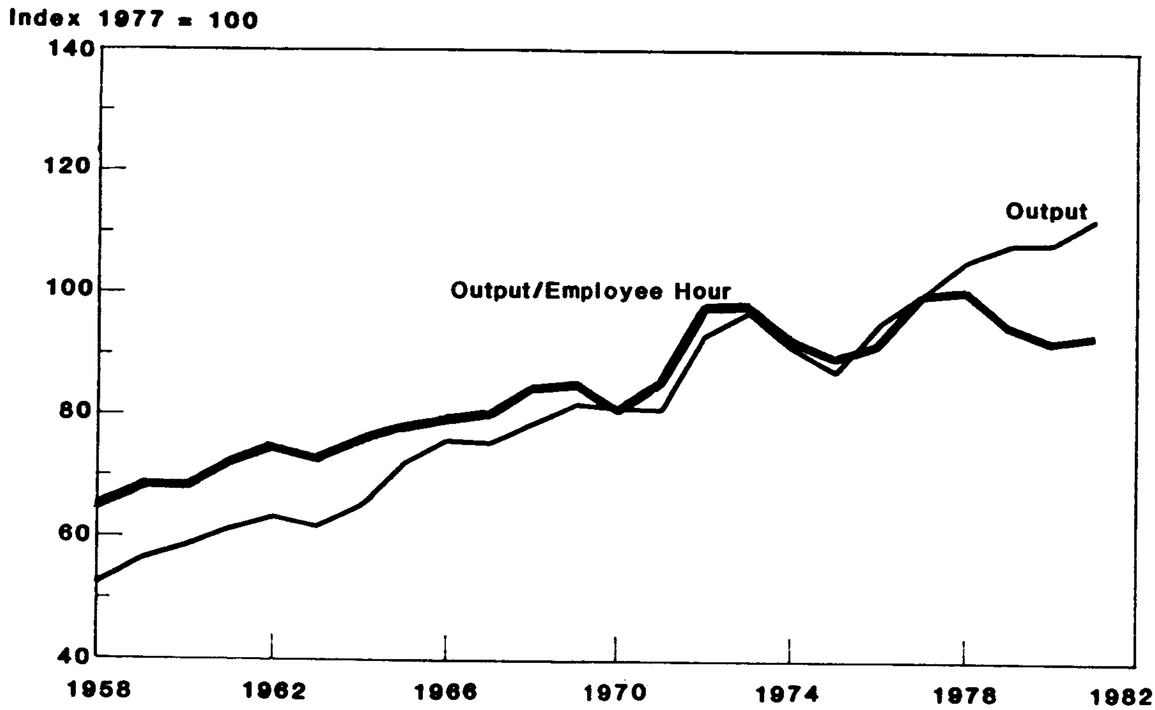
The commercial printing subdivision is composed of establishments largely concerned with printing as opposed to publishing. The major products of this subdivision include advertising matter, periodical printing, general jobs, financial and legal printing, labels, catalogs and directories.

The subdivision's business and structural profiles are summarized in Tables 9-11 and 9-12, respectively. Table 9-11 indicates that receipts have increased by only 19% from $9.1 billion

TABLE 9-11

BUSINESS PROFILE OF THE
COMMERCIAL PRINTING INDUSTRY (SIC 275)

	1972	1977	1979	1981	1983
RECEIPTS (BILLION $)					
CURRENT $	9.1	14.7	18.6	23.1	26.7
1972 $	9.1	9.6	10.3	10.8	11.0
TOTAL EMPLOYMENT (THOUSANDS)	334.5	346.2	392.8	411.3	436.0



VALUE OF PLANT, 1976, CURRENT $, BILLION 4.5

	1977	1981
NEW CAPITAL EXPENDITURES, CURRENT $, BILLION	0.6	1.2

SOURCES: U.S. DOC/BOC: CENSUS OF MANUFACTURES
U.S. DOC/BIE: 1984 U.S. INDUSTRIAL OUTLOOK
U.S. DOL/BLS
ARTHUR D. LITTLE, INCORPORATED

TABLE 9-12

STRUCTURAL PROFILE OF THE COMMERCIAL PRINTING INDUSTRY (SIC 275)

ESTABLISHMENTS (1977) (CATEGORIZED BY NO. OF EMPLOYEES)		**LEADING FIRMS (1983)** NAME	DOMESTICALLY GENERATED SALES ($MILLION)
SMALL (<20)	23,177	R.R.DONNELLEY	1,268
INTERMEDIATE (20-1000)	3,626	MEREDITH CORP.	273
LARGE (>1000)	12	W.A.KRUEGER	182
		INTERNATIONAL BANK NOTE	165
		PANDICK, INC.	21
TOTAL (26,109 COMPANIES)	26,815	TOTAL	1,909

	MFG. LABOR	OTHER LABOR	MATERIALS	ENERGY	CAPITAL
PRODUCTION COST DISTRIBUTION, 1977	22%	10%	42%	1%	25%

SOURCES: U.S. DOC/BOC: CENSUS OF MANUFACTURES
VALUE-LINE INVESTMENT SURVEY, 1984
ARTHUR D. LITTLE, INCORPORATED

to $10.8 billion (constant 1972 $) from 1972 to 1983. Employment increased by 30% during the same time period. Output per employee hour has dropped in the last few years indicating a slight decrease in labor productivity. As shown in Table 9-12, the industry is dominated by five major firms. Most companies seem to be single establishment organizations (26,109 companies versus 26,815 establishments). Materials and labor account for most of the production costs at 42% and 32%, respectively.

As shown in Table 9-13, three institutional constraints seem to affect the industry. Although printers did not experience any major problems with input materials and supplies in 1983, past instances of paper and pressroom chemical shortages have occurred, causing severe production disruptions. A lack of skilled workers in some segments of the industry may create bottlenecks as demand for printing services continue to rise.

More importantly, the corporate structure of the industry, with its high degree of fragmentation and one-to-one correspondence of company and establishment, limits the amount of internal R&D effort. The industry must rely on external sources for technological developments. Because of small company size and volume and lack of expertise, commercial printers may purchase many prepress services, particularly for color. Technology cost effectiveness becomes a key issue. New, specialized technologies may not be practical or economically feasible.

Competitive Issues Affecting the Commercial Printing Industry

Printed products are traded internationally, primarily for their unique content, rather than for reasons of economics. Books constitute the greatest share of U.S. printing exports and imports. For obvious linguistic reasons, Canada and the United Kingdom are the primary foreign markets and suppliers.

TABLE 9-13

DOMINANT CONSTRAINTS AFFECTING THE COMMERCIAL PRINTING INDUSTRY (SIC 275)

MATERIAL	PRECEDENTS EXIST FOR MATERIAL SHORTAGES IN PAPER AND PRESS ROOM CHEMICALS.
LACK OF SKILLED WORKERS	SHORTAGES OF SOME OCCUPATIONAL SKILLS IN SELECTED AREAS
ESTABLISHMENT ORGANIZATION	THE SMALL CORPORATE AND ESTABLISHMENT SIZE AND THE EXTREME AMOUNT OF FRAGMENTATION PRECLUDES THE OPPORTUNITY FOR INTRA-INDUSTRY R&D ACTIVITIES. THIS SITUATION ALSO LENDS TO THE LACK OF JUSTIFICATION FOR IN-HOUSE TECHNOLOGY APPLICATIONS BECAUSE OF SMALL VOLUME.

SOURCES: U.S. DOC/BIE: 1984 U.S. INDUSTRIAL OUTLOOK
ARTHUR D. LITTLE, INCORPORATED

However, foreign trade in printing represents a relatively small fraction of the total industry production. Of more importance is the domestic competition represented by consumer electronic information delivery and newspapers. To hold existing markets and expand into new areas, printing companies will need to use the most efficient, productive machinery and employ aggressive, well-trained personnel specializing in marketing and new product development. Consumers will increase their demand for the latest, most advanced products that use modern techniques. Printers will have to develop flexibility in order to meet these demands.

Productivity in Commercial Printing

Productivity measures for commercial printing processes are easier to discern than in newspapers, since these processes do not involve the publishing aspect. Large establishments of over 500 employees had the largest increases in productivity averaging 73%. Smaller firms experienced smaller growth rates in productivity, ranging from 24 to 33%. Since the industry is dominated by small firms unable to benefit from economies of scale as in larger firms and currently unable to afford the state-of-the-art machinery that would bolster their productivity rates considerably, productivity growth will continue to be restricted.

Role of Technology in Long-term Strategic Outlook

Historically, printing technologies evolve slowly and painfully because of the large production network of which they are a part and because their productive value is measured subjectively. This is particularly true with color printing in which any subtle change in one color can completely change the overall aesthetic quality of the product. For example, it took ten years of trial and error by printers and equipment vendors to demonstrate the technical and economic feasibility of partially integrated prepress text-processing sytems.

Table 9-14 suggests the possible scope of technological advances in the commercial printing industry with regards to the three categories of operation: prepress, printing, and assembly. More specific technological advances will be similar to those found in the newspaper industry (see Table 9-9).

B.9.3 CONCLUSIONS

The subdivisions of the printing and publishing industry do not show the characteristics of "sunrise" or "sunset" industries, rather those of mature industries maintaining a linear advancement. Small increases in volume and productivity have helped to offset the effects of the recent recession and competition from other media.

Core problems will continue to affect the industry. These include:

- Poor product delivery via manual and local transportation means;
- Small incremental increases in productivity rather than significant gains;
- Increased competition with electronic media and changing consumer preferences;
- Lack of internal R&D programs.

Although the fragmented industry will not likely initiate technological development, it will continue to implement the technologies supplied by highly specialized domestic or foreign private companies. This will particularly include those advances that benefit prepress operations. Foreign technologies will play an increasingly important role, especially those from Great Britain, Germany, Japan and Israel.

TABLE 9-14

TECHNOLOGICAL ADVANCES IN THE COMMERCIAL PRINTING INDUSTRY (SIC 275)

PREPRESS

- INCREASED USE OF ELECTRONIC COLOR
- ELECTRONIC PAGINATION AND IMPOSITION OF COLOR
- SEVERAL OPTIONS FOR COMPUTER-TO-PLATE FOR COLOR PRINTING

PRINTING

- CLOSED LOOP SENSING AND CONTROL FOR COLOR PRINTING
- POTENTIAL MULTI-PLANT PRINTING CAPABILITY VIA ELECTRONIC OR SATELLITE COMMUNICATION

ASSEMBLY

- MORE COMPLETE AUTOMATION VIA ELECTRONIC SENSING AND CONTROLS

SOURCE: ARTHUR D. LITTLE, INCORPORATED

TABLE 9-15

RELATIVE LEVELS OF TECHNOLOGY IN PRINTING

	1984			2010		
APPLICATION	**PRE-PRESS**	**PRINT**	**ASSEMBLY**	**PRE-PRESS**	**PRINT**	**ASSEMBLY**
NEWSPAPERS	HIGH	LOW	NIL	SLIGHTLY HIGHER	MODERATE INCREASE	NIL
PERIODICALS	HIGH	MODERATE	LOW	VERY HIGH	MODERATE INCREASE	MODERATE INCREASE
COMMERCIAL PRINTING	HIGH	MODERATE	LOW	VERY HIGH	MODERATE INCREASE	MODERATE INCREASE

SOURCE: ARTHUR D. LITTLE, INCORPORATED

Electronic technology will continue to affect the processes involved in printing, especially at the prepress stage. Table 9-15 illustrates the relative levels of technological diffusion now and in the year 2010. Electronic graphic techniques will continue to evolve slowly. Possible advances may include digital colored image processing.

Clearly, print is faced with competitive technology that can deliver information to the consumer faster than printers can deliver hard copy. Consumer preference will be a key issue. Imposed on that will be the perception of the advertiser and publisher of how best to present and sell their information. Print may erode slowly in the face of consumer electronic information delivery as advertising dollars are diverted from print to electronic media, but technological advances will also help printing and publishing to maintain a competitive posture.

B.10 "PAPER AND ALLIED PRODUCTS" (SIC 26)

TABLE OF CONTENTS

SOURCES: U.S. DOC/BOC:

Statistical Abstract of the U.S., 1984
Census of Manufactures, 1977
Annual Survey of Manufactures, 1981

U.S. DOC/BIE:

1984 U.S. Industrial Outlook

EOP/OMB:

Standard Industrial Classification Manual, 1972

EPA:

1984 Cost of Clean Air and Water Report to Congress

Value-Line Investment Survey, 1984

U.S. DOL/BLS

LIST OF TABLES

B.10 "PAPER AND ALLIED PRODUCTS" (SIC 26)

Paper and allied products, SIC 26, comprises the tenth largest manufacturing subsector. Its value added accounted for 3.7% of the manufacturing sector's contribution to GDP in 1980. The subsector is characterized by:

- A moderate degree of fragmentation. Out of a total of approximately 6,500 establishments, 2,500 employed less than 20 persons (1977).

- A labor productivity of $25,808 per employee year or $13.44 per employee hour (1980, 1972 $), ranking this subsector fifth among the nation's 20 manufacturing subsectors. A compound annual labor productivity growth rate average of 2.8%/year from 1972 to 1980 ranks this subsector second. The labor productivity for the comparable Japanese subsector was $12,459 per employee year or $6.49 per employee hour (1980, 1972 $), ranking this subsector ninth among Japan's 20 manufacturing subsectors. The compound annual labor productivity growth rate for the Japanese subsector averaged 5.0%/year from 1972 to 1980, ranking this subsector tenth.

- A higher than average capital investment base relative to other subsectors within the manufacturing sector. Capital investment amounted to $36,632 in total assets per worker, ranking third in terms of (depreciated) fixed assets (1980, 1972 $). New yearly capital expenditures were $4,447 per employee (1980, 1972 $), ranking third in the manufacturing sector. Total capital productivity, measured as dollars of added value output per dollar of capital investment, was 0.43 (1980).

- A less than average R&D program. For the subsector as a whole, R&D expenditures amounted to $0.3 billion (1980, 1972 $), ranking this subsector eleventh among the 20 manufacturing subsectors. R&D expenditures were equivalent to 1.7% of the value added by the subsector in 1980.

Table 10-1 shows the major products of each subdivision of the paper and allied products subsector, ranked in descending order in terms of their share of the subsector's contribution to GDP in 1980. Table 10-2 summaries the principal economic measures of these subdivisions.

As shown, three subdivisions--Miscellaneous Converted Paper Products (SIC 264); Papermills, except Building Paper (SIC 262); and Paperboard Containers and Boxes (SIC 265)--accounted for 82.1% of the subsector's output in 1980. In assessing long-term technology needs, we have selected these three subdivisions for further analysis.

The business and structural profiles of the subdivisions will be examined independently, while constraints and technologies will encompass the entire subsector.

B.10.1 MISCELLANEOUS CONVERTED PAPER PRODUCTS (SIC 264)

The miscellaneous converted paper products industry manufactures a wide variety of products including adhesive tape, envelopes, bags, egg cartons, paper plates, facial tissue, stationery and wallpaper. The major markets for this industry are consumer retail outlets, all manufacturing and service industries, and the construction industry.

The subdivision's historical and current posture is summarized in Tables 10-3 and 10-4, which portray the industry's business and structural profiles, respectively. Table 10-3 shows

TABLE 10-1

CLASSIFICATION OF MAJOR PRODUCTS OF THE PAPER AND ALLIED PRODUCTS INDUSTRY (SIC 26) AND CONTRIBUTION TO SUBSECTOR IN 1980

SIC CODE	SUBDIVISION DESIGNATION AND TYPICAL PRODUCTS	% CONTRIBUTED
264	**MISCELLANEOUS CONVERTED PAPER PRODUCTS**	34.3
	BOOKPAPER, FLYPAPER, TAPE, TOWELETTES, WAXED PAPER, ENVELOPES, BAGS, CARDBOARD, EGG CARTONS, DISHES, TISSUES, TOILET PAPER, STATIONERY, AND HONEYCOMBS.	
262	**PAPERMILLS, EXCEPT BUILDING PAPER**	26.0
	BAG PAPER, NEWSPRINT, WALLPAPER STOCK, TAGBOARD, PRINTING PAPER, TISSUE PAPERSTOCK, AND CIGARETTE PAPER.	
265	**PAPERBOARD CONTAINERS AND BOXES**	21.8
	FOLDING PAPERBOARD BOXES, SET-UP PAPERBOARD BOXES, CORRUGATED BOXES, SOLID FIBER BOXES.	
263	**PAPERBOARD MILLS**	12.9
	BINDERS BOARD, CHIPBOARD, FOLDING BOXBOARDS, MILK CARTON BOARD, PRESS BOARD, AND TAGBOARD.	
261	**PULP MILLS**	4.3
	FIBER PULP, RAYON PULP, WOOD PULP, AND PULP.	
266	**BUILDING PAPER AND BOARDMILLS**	0.7
	ASBESTOS PAPER, ASPHALT PAPER, DRY FELTS.	
26	**ALL PAPER AND ALLIED PRODUCTS**	100.0

SOURCES: U.S. DOC/BOC: STATISTICAL ABSTRACT OF THE U.S., 1984
EOP/OMB: STANDARD INDUSTRIAL CLASSIFICATION MANUAL, 1972

TABLE 10-2

SUBDIVISIONS AND CHARACTERIZATION OF THE PAPER AND ALLIED PRODUCTS INDUSTRY (SIC 26) DURING 1980, IN 1972 DOLLARS

SUBDIVISION	ADDED VALUE RELATIVE CONTRIBUTION(%)	NUMBER OF EMPLOYEES (1,000)	NUMBER OF ESTABLISHMENTS[a]			GROSS VALUE OF FIXED ASSET ($/EMPLOYEE)	NEW CAPITAL EXPENDITURES ($/EMPLOYEE)	LABOR PRODUCTIVITY ($/EMPLOYEE)
			TOTAL	LESS THAN 20 EMPLOYEES	100 OR MORE EMPLOYEES			
ALL PAPER AND ALLIED PRODUCTS	100	646.3	6,545	2,545	1,724	36,532	4,447	25,808
PULPMILLS (261)	4	16.2	45	3	30	113,603	8,660	44,724
PAPERMILLS, EXCEPT BUILD PAPER (262)	24	130.1	339	52	221	71,498	8,171	33,205
PAPERBOARD MILLS (263)	14	64.0	249	17	146	85,952	13,475	33,496
MISCELLANEOUS CONVERTED PAPER PRODUCTS (264)	33	228.7	2,994	1,558	543	15,675	1,898	25,114
PAPERBOARD CONTAINERS AND BOXES (265)	24	200.6	2,860	910	762	15,670	1,754	18,061
BUILDING PAPER AND BOARDMILLS (266)	1	6.7	58	5	22	35,611	3,380	18,696

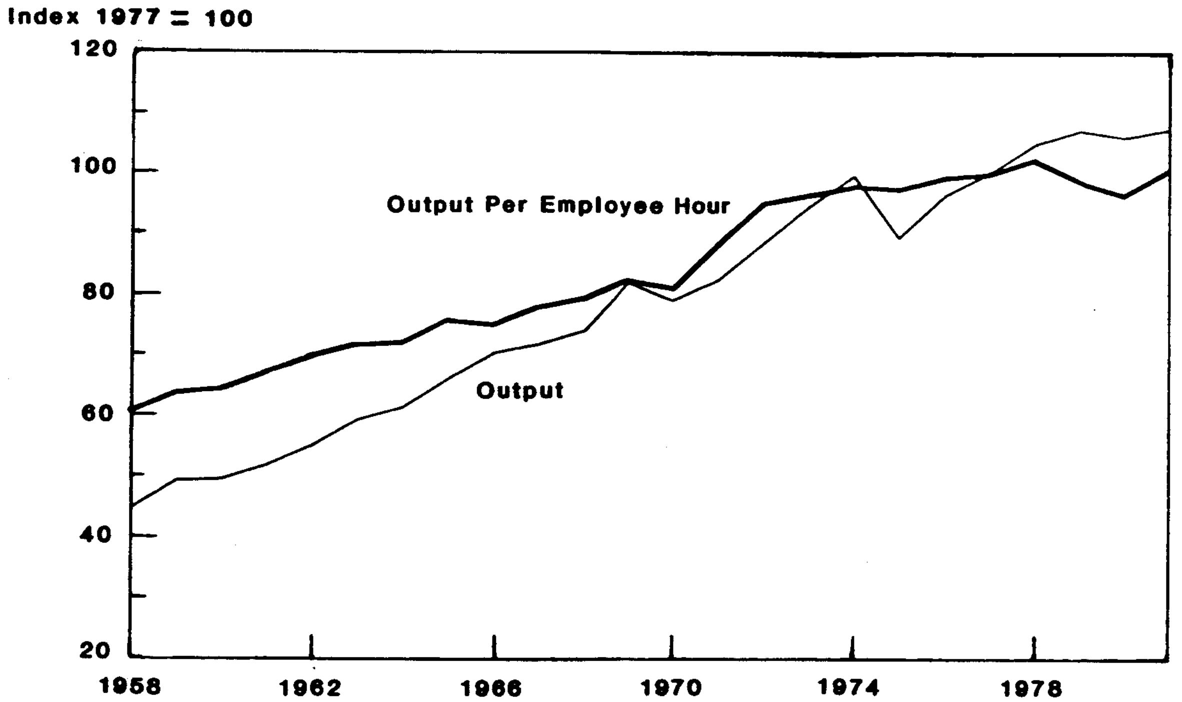
[a] 1977

SOURCE: U.S. DOC/BOC: CENSUS OF MANUFACTURES, 1977
U.S. DOC/BOC: ANNUAL SURVEY OF MANUFACTURES, 1981

TABLE 10-3

BUSINESS PROFILE OF THE MISCELLANEOUS CONVERTED PAPER PRODUCTS INDUSTRY (SIC 264)

SHIPMENTS (BILLION $)	1972	1977	1979	1981	1983	1984 EST.
CURRENT $	8.5	16.4	21.2	26.1	27.3	—
1972 $	8.5	9.6	10.3	10.3	10.4	10.8
TOTAL EMPLOYMENT (THOUSANDS)	189.1	206.7	230.2	221.5	218.3	221.6



Source: Unpublished BLS Data

VALUE OF PLANT, 1976, CURRENT $ BILLION 4.0

NEW CAPITAL EXPENDITURE, CURRENT $, BILLION	1977	1981
	0.50	0.74

SOURCES: U.S. DOC/BIE: 1984 U.S. INDUSTRIAL OUTLOOK
U.S. DOC/BOC: CENSUS OF MANUFACTURES, 1977
VALUE-LINE INVESTMENT SURVEY, 1984

TABLE 10-4

STRUCTURAL PROFILE OF THE
MISCELLANEOUS CONVERTED PAPER PRODUCTS INDUSTRY (SIC 264)

ESTABLISHMENTS (1977)
(CATEGORIZED BY NO. OF EMPLOYEES)

SMALL (>20)	1558
INTERMEDIATE (20-1000)	1422
LARGE (<1000)	14
TOTAL (2323 COMPANIES)	2994

LEADING FIRMS (1983)

NAME	DOMESTICALLY PRODUCED SALES ($ BILLIONS)
KIMBERLY-CLARK CORP.	2.6
INTERNATIONAL PAPER	2.1
CHAMPION INTERNATIONAL	1.9
JAMES RIVER CORP. OF VA	1.6
ST. REGIS CORP.	1.4
MEAD CORP.	1.2
WEYERHAEUSER CO.	1.2
TOTAL	12.0

PRODUCTION COST DISTRIBUTION, 1977	MFG. LABOR	OTHER LABOR	MATERIALS	ENERGY	CAPITAL
	11%	5%	55%	1%	28%

SOURCES: U.S. DOC/BIE: 1984 U.S. INDUSTRIAL OUTLOOK
U.S. DOC/BOC: CENSUS OF MANUFACTURES, 1977
VALUE-LINE INVESTMENT SURVEY, 1984

that industry shipments, expressed in constant 1972 dollars, have increased only 22% in eleven years, from \$8.5 billion in 1972 to \$10.4 billion in 1983. The 1984 forecast is for shipments of \$10.8 billion (in 1972 \$), an increase of 3.8% over 1983. Employment has steadily increased, rising 15.4% from 189,000 in 1972 to 218,300 in 1983. Labor productivity, i.e., output per employee hour, has steadily increased.

Table 10-4 shows that the miscellaneous converted paper products industry is comprised of 2980 small and intermediate establishments. The 14 large establishments account for almost half of the domestically produced sales. The cost of finished products is dominated by the cost of input material (55%); manufacturing labor accounts for 11% of total costs.

The two largest industries of this subdivision, based on the value of shipments, are sanitary paper products (SIC 2647) and paper coating and glazing (SIC 2641). Sanitary paper products is the only industry in the paper and allied products subsector that did not suffer during the recession of the early 1980s, with the value of shipments showing modest increases of 2% in 1982 and 3% in 1983. For the most part its product lines, which are of a nondiscretionary nature, have reached market saturation level and, therefore, do not show large gains. The exception is disposable diapers, which continues to show yearly growth.

Due to the large consumer market for the products of this industry, most of the technological developments are those which lead to lower "per unit" costs as well as technological improvements which increase the strength, softness and absorbency of the paper.

Paper coating and glazing (SIC 2641), the second largest industry within this subdivision, produces principally tapes (both paper and nonpaper), labels, and goods that are coated, laminated, impregnated or surface-treated. The recent development of repulpable tape for industrial use, for which the principal markets are the U.S.S.R., Canada, F.R. Germany, and Japan, has allowed the industry to show continued gains in export volumes. Paper coating and glazing is concentrating on the development of new industrial and consumer markets, increasing the use of automated tape and label application, and on the use of computerized-label imprinting equipment.

B.10.2 PAPERBOARD CONTAINERS AND BOXES (SIC 265)

The paperboard containers and boxes subdivision is comprised of establishments that manufacture folding paperboard boxes, set-up paperboard boxes, corrugated and solid fiber boxes, sanitary food containers, and fiber cans, tubes, and drums. Business and structural profiles of the paperboard containers and boxes subdivision are summarized in Tables 10-5 and 10-6.

Table 10-5 shows that industry shipments have increased by only 6.6%, measured in 1972 constant dollars, from \$8.1 billion in 1972 to \$8.6 billion in 1983. In 1977 and 1979, however, shipments were \$9.1 and \$9.2 billion respectively. Shipments in 1981 decreased to \$8.7 billion and to \$8.6 in 1983. Employment has steadily decreased, dropping 14.5% from 223,700 in 1972 to 191,200 in 1983. Employment is expected to increase in 1984 to 194,900.

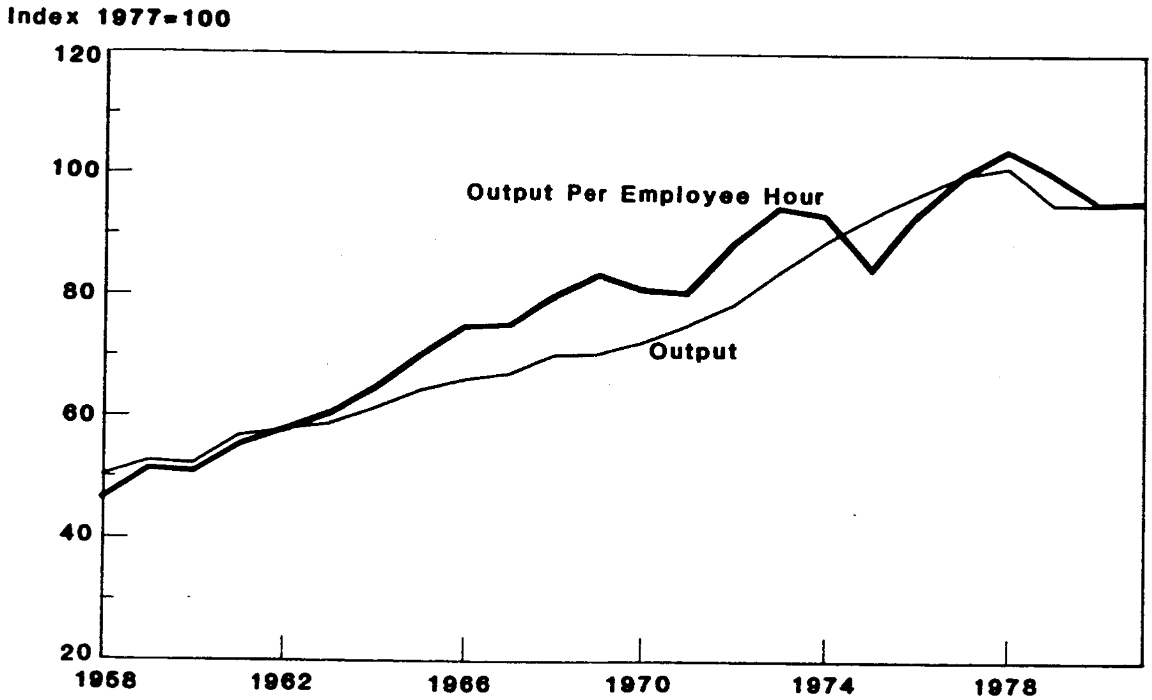
The output of folding paperboard boxes increased between 1963 and 1982 at an average annual rate of 6%. The period between 1963 and 1973 showed an average gain of only 0.3% per year, but from 1973 to 1982 the rate rose to an average of 0.9% per year. The low annual growth rate was a result of changes in product mix and the use of less dense boxes, which lowered tonnage figures.

The output for the 1982-87 period is projected to increase at an annual rate of 1.2%. However, the increasing use of plas-

TABLE 10-5

BUSINESS PROFILE OF THE
PAPERBOARD CONTAINERS AND BOXES INDUSTRY (SIC 265)

SHIPMENTS (BILLION $)	1972	1977	1979	1981	1983	1984 EST.
CURRENT $	8.10	13.35	15.98	19.01	19.86	—
1972 $	8.10	9.12	9.20	8.73	8.64	8.92
TOTAL EMPLOYMENT (THOUSANDS)	223.7	204.1	209.0	199.8	191.2	194.9



Source: Unpublished BLS Data

VALUE OF PLANT, 1976, CURRENT $, BILLION 4.3

NEW CAPITAL EXPENDITURE CURRENT $, BILLION	1977	1981
	0.51	0.50

SOURCES: U.S. DOC/BIE: 1984 U.S. INDUSTRIAL OUTLOOK
U.S. DOC/BOC: CENSUS OF MANUFACTURES, 1977

TABLE 10-6

STRUCTURAL PROFILE OF THE
PAPERBOARD CONTAINERS AND BOXES INDUSTRY (SIC 265)

ESTABLISHMENTS (1977)
(CATEGORIZED BY NO.
OF EMPLOYEES)

SMALL (<20)	910
INTERMEDIATE (20-1000)	1945
LARGE (>1000)	5
TOTAL	2860
(1794 COMPANIES)	

LEADING FIRMS (1983)

NAME	DOMESTICALLY PRODUCED SALES ($ MILLION)
INTERNATIONAL PAPER CO.	1524.95
ST. REGIS CORP.	943.36
CHAMPION INTERNATIONAL	810.16
WEYERHAEUSER COMPANY	781.22
UNION CAMP CORPORATION	641.55
MEAD CORPORATION	591.65
TOTAL	591.65

	MFG. LABOR	OTHER LABOR	MATERIALS	ENERGY	CAPITAL
PRODUCTION COST DISTRIBUTION, 1977	13%	6%	59%	2%	20%

SOURCES: U.S. DOC/BIE: 1984 U.S. INDUSTRIAL OUTLOOK
U.S. DOC/BOC: CENSUS OF MANUFACTURES, 1977
VALUE-LINE INVESTMENT SURVEY, 1984

tics and other substitute materials may limit the growth of folding paperboard boxes.

Productivity in the folding paperboard boxes industry between 1963 and 1982 increased at an average annual rate of 1.9% based on output per employee hour. During the same period productivity for manufacturing as a whole, however, increased at an average annual rate of 2.3%. During 1970 and 1976 productivity rose at an annual rate of 3.0%. This productivity gain was due to the introduction of improved technology and production methods. The incentive to adopt more efficient technology was initiated by competition from substitute materials.

Table 10-6 indicates that the four largest firms in the folding paperboard box industry account for 22% of total annual shipments. Approximately 43% of the volume of these shipments are used in the packaging of food and beverages.

The two largest industries in this subdivision, based on the value of shipments, are corrugated and solid fiber boxes (SIC 2653) and folding paperboard boxes (SIC 2651). The corrugated and solid fiber boxes industry includes an estimated 850 to 875 companies that operate 631 corrugating or converting establishments and 748 sheeting facilities that purchase corrugated board from converters and manufacture boxes from that board. The converting establishments require higher capital costs because of sophisticated technologies used in their operations. Converting establishments accommodate high-volume and long-run orders, whereas sheeting establishments are designed to accommodate small, specialty orders.

The growth of the folding paperboard and corrugated and solid-fiber box industries in the future will depend on several factors: the strength of competition from plastics and other types of paperboard containers; implementation of computerization and automatic packaging machinery and equipment; continuing development of the cold corrugating process; and development of increased container board strengths.

B.10.3 PULP, PAPER, AND BOARD MILLS (SICs 2611, 2621, 2631, 2661)

The pulp, paper and board mills industries manufacture pulp, paper, paperboard, and paper building board from wood or other materials. The business and structural profiles of these industries are summarized in Tables 10-7 and 10-8.

At the present time these industries are healthy. Table 10-7 indicates that shipments of wood pulp increased by 5.6% and those of paper and board products by 7.3% in 1982. This pattern is expected to continue through 1988 with an average annual growth rate of 2.6%. Market demand (both foreign and domestic) and foreign market competition will influence these growth rate projections, which are lower than previously anticipated because of a slowdown in overall economic growth. These industries will be compelled to intensify the development of cost-saving techniques to ensure the fulfillment of these growth rate projections.

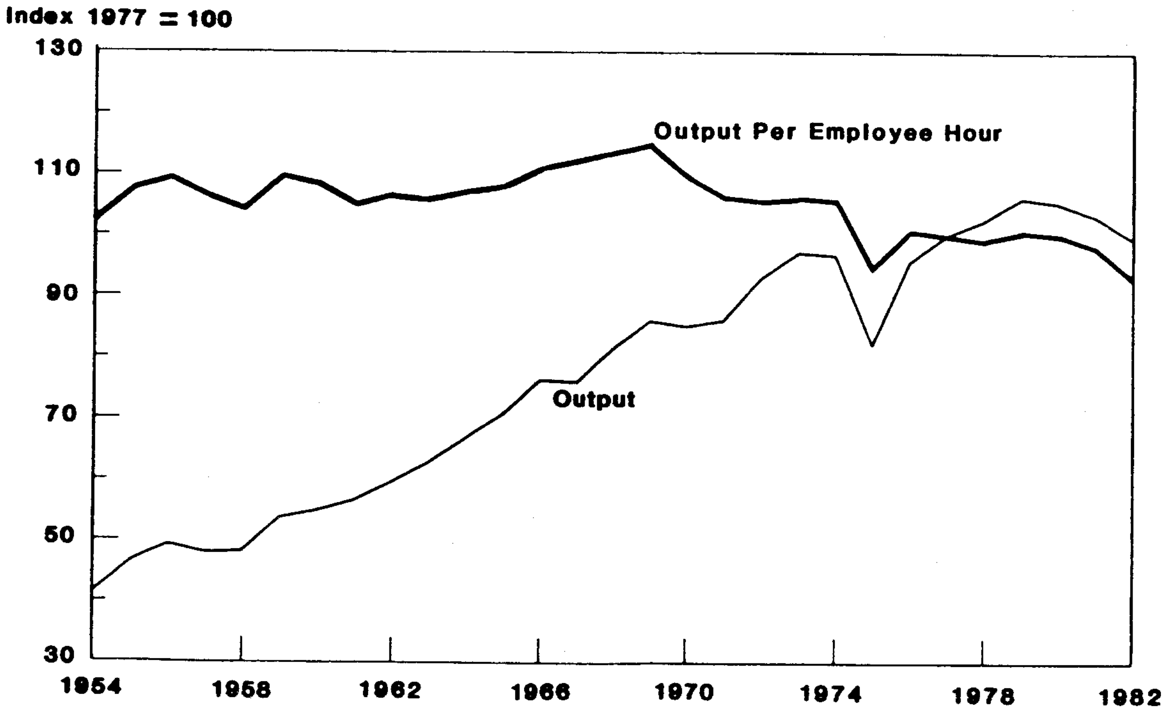
Table 10-8 indicates the pulp, paper and board industries are heavy users of energy. At the present time, approximately 50% of the industry's energy requirements are obtained from generated wastes and residues. However, the industry is also a heavy user of natural gas and fuel oils. It is therefore important to develop technologies that would reduce this energy consumption, especially if energy prices become deregulated.

The pulp and paperboard industries have invested a great deal of money in upgrading operating facilities to meet current air, water and solid waste environmental standards. The higher costs of paperboard materials that result from this investment make it difficult to compete in third-world markets where envi-

TABLE 10-7

BUSINESS PROFILE OF THE
PULPMILLS, PAPER MILLS, AND BOARD MILLS INDUSTRIES
(SICs 2611, 2621, 2631, 2661)

SHIPMENTS (BILLION $)	1972	1977	1979	1981	1983	1984 EST.
CURRENT $	11.7	22.3	27.9	35.1	36.5	—
1972 $	11.7	13.3	14.4	14.6	14.9	15.7
TOTAL EMPLOYMENT THOUSANDS	220.6	217.8	218.5	214.5	202.6	208.2



Source: Published BLS Data

VALUE OF PLANT, 1976, CURRENT $, BILLION — 20.0

NEW CAPITAL EXPENDITURES

	1977	1981
CURRENT $, BILLION	2.37	3.41

AVERAGE ANNUAL COSTS OF POLLUTION CONTROL

(MILLION 1972 $)	1970-78	1980-90
AIR	46.4	153.6
	1972-78	1981-90
WATER	158.2	373.8

SOURCES: U.S. DOC/BIE: 1984 U.S. INDUSTRIAL OUTLOOK
U.S. DOC/BOC: CENSUS OF MANUFACTURES
EPA: 1984 COST OF CLEAN AIR AND WATER REPORT TO CONGRESS

TABLE 10-8

STRUCTURAL PROFILE OF THE
PULPMILLS, PAPER MILLS, AND BOARD MILLS INDUSTRIES
(SICs 2611, 2621, 2631, 2661)

ESTABLISHMENTS (1977) (CATEGORIZED BY NO. OF EMPLOYEES)		LEADING FIRMS (1983) NAME	DOMESTICALLY PRODUCED SALES ($ MILLION)
SMALL (<20)	77	GEORGIA-PACIFIC	1,674
INTERMEDIATE (20-1000)	562	GREAT NORTH NEKOOSA	1,126
		FEDERAL PAPER BOARD CO.	273
LARGE (>1000)	52	STONE CONTAINER	268
		LOUISIANA-PACIFIC	165
TOTAL (337 COMPANIES)	691	TOTAL	3,506

PRODUCTION COST DISTRIBUTION, 1977	MFG. LABOR	OTHER LABOR	MATERIALS	ENERGY	CAPITAL
	13%	4%	46%	11%	26%

SOURCES: U.S. DOC/BIE: 1984 U.S. INDUSTRIAL OUTLOOK
U.S. DOC/BOC: CENSUS OF MANUFACTURES, 1977
VALUE-LINE INVESTMENT SURVEY, 1984

ronmental standards are more lenient. Therefore, to improve its competitive position, the industry must develop new inexpensive technologies to meet environmental standards and lower pollution abatement costs.

B.10.4 CONSTRAINTS AND COMPETITIVE ISSUES

There are three dominant institutional factors which influence/constrain the paper and allied products industry. Table 10-9 indicates that the industry is strongly affected by government regulations, in particular those from the Environmental Protection Agency. Between 1970 and 1978 the average annual cost of pollution control was $46.4 million for air and $158.2 million for water (1972 $). It is projected that the average annual cost between 1981 and 1990 will rise to $153.6 million for air and $373.8 million for water. The paper industry is the largest user of water for processing purposes among all the U.S. manufacturing industries. As a result, the industry is affected by stricter state and federal government clean water standards. Also stricter regulations regarding air quality and solid waste have also affected the industry. As a result of the stricter regulations, capital requirements for new pollution abatement facilities have increased operating costs and capital intensity.

Energy costs for production are high for this industry, especially for the wood pulp and paper pulp subdivisions where energy costs are 11% of total production costs. The paper industry is one of the ten most energy intensive industries. It is a heavy user of natural gas and residual oils and as such will face higher costs if these are totally deregulated. At the same time, however, the industry is in a favorable position to enjoy the economic benefits available through cogeneration of steam and electricity.

TABLE 10-9

DOMINANT CONSTRAINTS AFFECTING THE PAPER AND ALLIED PRODUCTS INDUSTRY (SIC 26)

GOVERNMENT REGULATIONS	NUMEROUS REGULATIONS DEALING WITH AIR AND WATER POLLUTION CONTROL AFFECT EACH SUBDIVISION TO VARYING DEGREES.
FUEL PRICES	PRODUCTION COSTS AFFECTED BY OIL, COAL, GAS, AND ELECTRICITY COSTS. ENERGY REQUIREMENTS IN 1977 FOR PRODUCTION ACCOUNTED FOR $2.7 BILLION OR 5.3% OF SHIPMENTS.
CAPITAL INVESTMENT	CAPITAL INVESTMENT AMOUNTED TO $36,632 (1980, 1972 $) IN TOTAL ASSETS PER WORKER.

Table 10-10 outlines the export and import statistics of the paper and allied products sector. Exports play an important role in this industry even though the industry is mainly aimed at satisfying the domestic market. The U.S. is a major world supplier of bleached sulfate pulp, linerboard, dissolving pulp, wastepaper, printing and writing paper, and special foodboard. Wastepaper exports have shown the fastest growth profile among the major pulp and paper trading items, climbing 40% during the 1981-83 period and accounting for 50% of the total dollar value of 1983 exports. The leading regional foreign markets for U.S. paper exports are Southeast Asia, Eastern Europe, Mexico, and Central America. The leading country markets for U.S. exports of paper products are Japan and Canada. Japan accounted for 14% of the total value of exports ($629 million), while Canada accounted for 13.6%.

The U.S. is, however, a net importer of newsprint and wood pulp from Canada. The charts in Table 10-10 compare the production of newsprint in the U.S. and in Canada and the U.S. consumption and imports of newsprint. The escalating imports of newsprint, uncoated printing and writing papers, and wrapping papers have contributed to the growing trade imbalance in the paper and allied products industry.

B.10.5 ROLE OF TECHNOLOGY IN LONG-TERM STRATEGIC OUTLOOK

Technological developments in many of the paper and allied products industries are aimed at improving already existing technology to increase productivity, improve quality, and save raw materials. For instance, in sanitary paper products, new developments are largely those that lead to lower unit costs or improvements in the strength, softness, or absorbency of the paper.

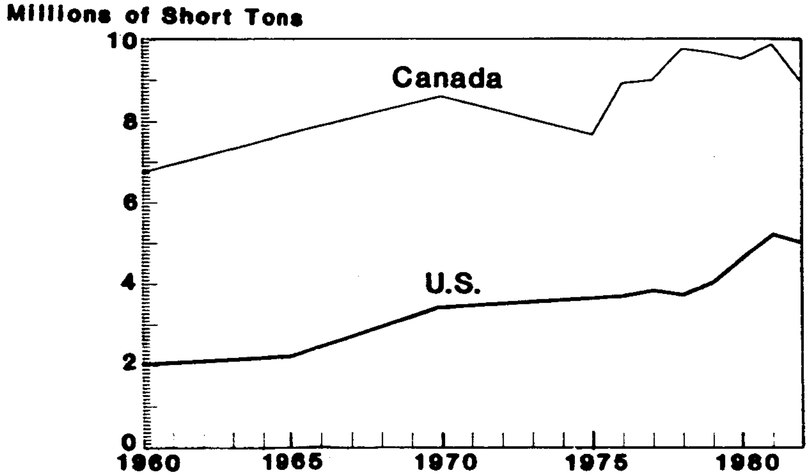
New technological developments have diffused into the paperboard box industry more slowly than into most other manufacturing subsectors. To cope with competition from plastics and other

TABLE 10-10

COMPETITIVE POSTURE OF THE PAPER AND ALLIED PRODUCTS INDUSTRY (SIC 26)

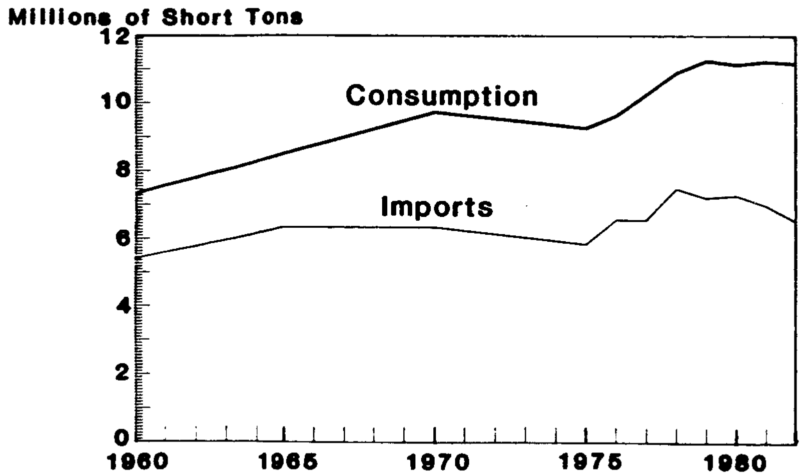
	1972	1977	1979	1981	1983	ANNUAL GROWTH RATE 1972-83
EXPORTS, (BILLION) CURRENT $	1.1	2.4	3.2	4.8	4.4	13.43%
IMPORTS, (BILLION) CURRENT $	1.8	3.6	5.0	5.8	5.6	10.87%
EXPORT/SHIPMENTS RATIO	0.02	0.05	0.05	0.06	0.05	
IMPORT/NEW SUPPLY RATIO	0.06	0.06	0.07	0.07	0.06	

NEWSPRINT PRODUCTION



Source: U.S. DOC/BOC:1984 Statistical Abstract

NEWSPRINT CONSUMPTION & IMPORTS INVESTMENTS



Source: U.S. DOC/BOC:1984 Statistical Abstract

SOURCES: U.S DOC/BIE: 1984 U.S. INDUSTRIAL OUTLOOK
U.S DOC/BOC: STATISTICAL ABSTRACT OF THE U.S., 1984

materials, the industry must increase technological development, thus addressing at the same time the demands of the major industrial markets (i.e., food and beverage, stone, clay and glass, and electrical machinery and equipment) and its need to raise productivity. Some of the major changes taking placing in the industry are listed in Table 10-11.

The continued growth of the pulp and paperboard industries depends on the development of inexpensive technologies to meet environmental standards and lower pollution abatement costs to enhance their competitive position in the world market. Table 10-12 shows the major areas of projected technological innovation in these industries.

Conclusions

The paper and allied products industry is a stabilized saturated industry. The industry is not revolutionary but evolutionary in terms of technological innovation. The majority of the R&D within the industry is conducted in universities and other industries, such as the machine tool industry. Although the paper and allied products industry experienced a drop in profits in 1982, it has historically been a steady profit making industry, i.e., one of the healthy U.S. "smoke stack" industries. While there are apparently no "leapfrog" technologies that would significantly contribute to this industry, advances in biotechnology relating to the accelerating of tree growth may help to reduce its trade deficit.

TABLE 10-11

MAJOR TECHNOLOGICAL CHANGES IN THE FOLDING PAPERBOARD BOXES AND CORRUGATED AND SOLID FIBER BOXES INDUSTRIES

TECHNOLOGY	DESCRIPTION
IMPROVED PRINTING PROCESSES	
• OFFSET PRINTING	PHOTOGRAPHIC METHODS ARE EMPLOYED TO PREPARE PRINTING PLATES. ALSO INCLUDES THE USE OF COMPUTERS TO CONTROL INK AND WATER FLOW RATES, PRESS SPEED, AND RELATED VARIABLES.
• GRAVURE PRINTING	PHOTOGRAPHIC METHODS TO PREPARE PRINTING CYLINDERS WITH TECHNOLOGICAL ADVANCES IN COLOR SCANNERS.
• FLEXOGRAPHY	FORM OF LETTERPRESS PRINTING WHICH UTILIZES LIGHT AND FLEXIBLE RUBBER OR PLASTIC PLATES.
RADIATION INK CURING	USE OF INFRARED AND ULTRAVIOLET INK CURING SYSTEMS WHICH REDUCE THE DELAY BETWEEN CARTON PRINTING AND CUTTING AND CREASING.
IMPROVED EQUIPMENT FOR CUTTING AND CREASING	NEW MODEL PLATEN CUTTING PRESSES THAT ARE FASTER THAN OLDER MODELS AND MATCH THE CAPACITY OF WEB-FED GRAVURE PRESSES.

APPROXIMATE ERA OF SIGNIFICANT DIFFUSION

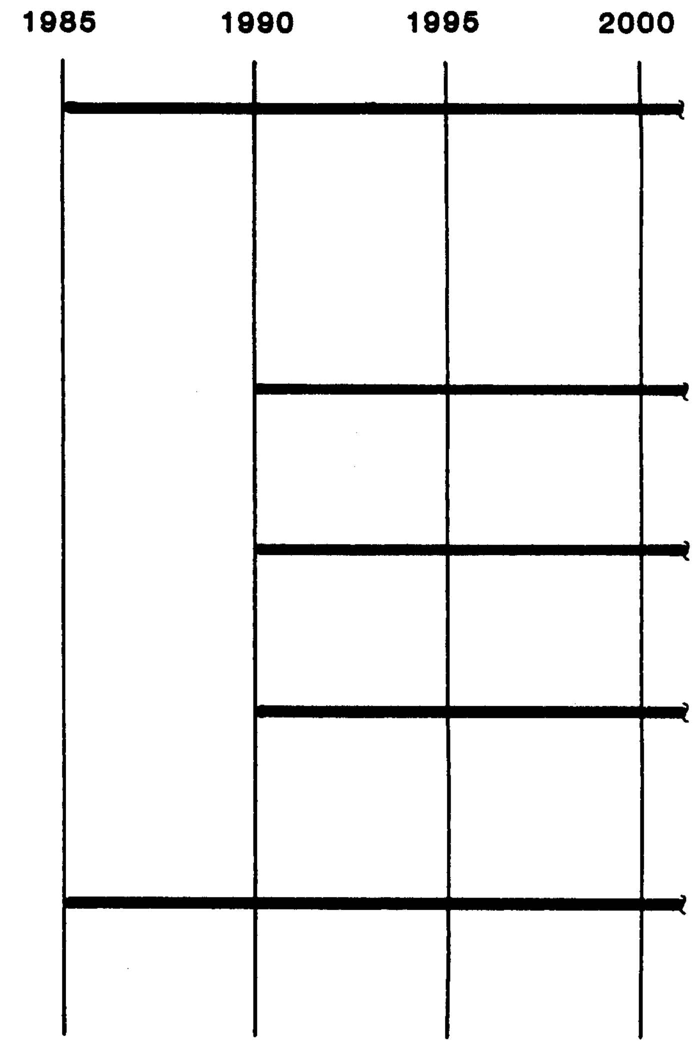
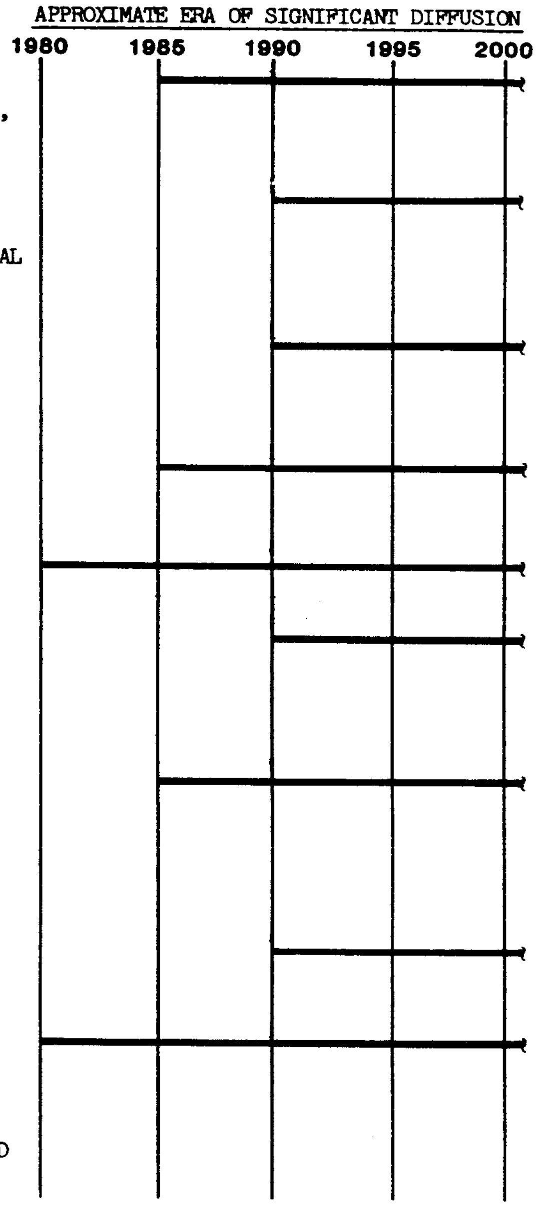


TABLE 10-12

MAJOR TECHNOLOGY CHANGES IN PULP, PAPER, AND BOARD INDUSTRIES (SICs 261, 262, 263, 266)

TECHNOLOGY	DESCRIPTION
MECHANIZATION OF MATERIALS HANDLING	IMPROVED CONVEYOR SYSTEMS WITH CENTRALIZED CONTROLS IN WOOD-HANDLING, FINISHING, AND SHIPPING DEPARTMENTS.
IMPROVED PULPING TECHNOLOGY	INNOVATIONS WHICH IMPROVE YIELD AND PULP QUALITY THROUGH THE USE OF COMPUTER CONTROL AS WELL AS MECHANICAL AND SEMICHEMICAL PULPING.
IMPROVEMENTS IN PAPER MAKING MACHINES	INCREASED SPEED OF FOURDRINIER MACHINES; TWIN-WIRE FORMING METHODS ARE REPLACING WIRE SCREEN.
COMPUTER CONTROL AND INSTRUMENTATION	USE OF COMPUTERS THROUGHOUT VARIOUS STAGES OF PULP AND PAPERMAKING PROCESSES.
POLLUTION CONTROL TECHNOLOGY	TECHNOLOGIES TO LESSEN AIR AND WATER POLLUTION.
COMPUTER AND LASER METHODS TO PREPARE THE DIES USED ON CUTTING AND CREASING PRESSES	UTILIZATION OF COMPUTERS TO GENERATE DIE LAYOUTS AND TO PRODUCE TAPES TO CONTROL LASERS IN DIE BOARD CUTTING.
AUTOMATIC STRIPPING OF PAPERBOARD WASTE	DEVICES WHICH AUTOMATICALLY REMOVE THE PAPERBOARD MATERIAL ATTACHED TO CARTON BLANKS AFTER CUTTING/CREASING.
NEW TECHNOLOGY TO GLUE CARTONS	FASTER DRYING GLUES, NEW AIR-BRUSH AND EXTRUSION GLUING.
IMPROVED PACKING METHODS	USE OF AUTOMATIC EQUIPMENT TO PLACE CARTONS IN CONTAINERS FOR SHIPPING; AUTOMATIC CONVEYOR SYSTEMS; AND USE OF FILM STRETCH STRAPS INSTEAD OF CORRUGATED CASES.



B.11 "INSTRUMENTS AND RELATED PRODUCTS" (SIC 38)

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B.11 "INSTRUMENTS AND RELATED PRODUCTS" (SIC 38)

Instruments and related products, subsector 38, is the eleventh largest manufacturing subsector. Its value added accounted for 3.3% of the manufacturing sector's contribution to the GDP in 1980. Salient characteristics of the subsector include:

- A high degree of fragmentation. Out of a total of approximately 7,481 establishments, 4,942 employed less than 20 persons (1977).

- A labor productivity of $25,381 per employee year or $13.22 per employee hour (1980, 1972 $), ranking this subsector sixth among the nation's 20 manufacturing subsectors. A compound annual labor productivity growth rate average of 1.0%/year from 1972 to 1980 ranks this subsector fifteenth. The labor productivity for the comparable Japanese subsectors was $9,512 per employee year or $4.95 per employee hour (1980, 1972 $), ranking this subsector fifteenth among Japan's 20 manufacturing subsectors. The compound annual labor productivity growth rate for the Japanese subsector averaged 5.2%/year from 1972 to 1980, ranking this subsector eighth.

- A lower than average capital investment base relative to other subsectors within the manufacturing sector. Capital investment amounted to $10,676 in total assets per worker, ranking fourteenth in terms of (depreciated) fixed assets (1980, 1972 $). New yearly capital expenditures were $1,520 per employee (1980, 1972 $). ranking thirteenth in the manufacturing sector. Total capital productivity, measured as dollars of added value output per dollar of capital investment, was 1.33 (1981).

- A moderately aggressive R&D program. For the subsector as a whole, R&D expenditures amounted to $1.7 billion (1980, 1972 $), ranking this subsector fifth among the 20 manufacturing subsectors. R&D expenditures were equivalent to 10.9% of the value added by the subsector in 1980.

Table 11-1 enumerates the major products produced by the industry ranked by contribution to the subsector. The principal economic measures of the industry's subsectors are summarized in Table 11-2.

Three subdivisions--Optical Instruments and Lenses (SIC 383), Surgical, Medical and Dental Instruments and Supplies (SIC 384), and Photographic Equipment and Supplies (SIC 386)--have been selected for detailed analysis. Collectively, these subdivisions account for 57.09% of the subsector's contribution to manufacturing.

B.11.1 OPTICAL INSTRUMENTS AND LENSES (SIC 383)

This subdivision is composed of establishments primarily engaged in the manufacture of all types of optical lenses, gunsights, magnifying and telescopic instruments, nuclear magnetic resonance and electron paramagnetic spin apparatus, optical measuring instruments, and fiber optical devices. The subdivision can be further divided into high-volume optics products and advanced optics products. Although this subdivision produces camera lenses, fully assembled cameras are not included in the products of this group.

The business and structural profiles of this industry are summarized in Tables 11-3 and 11-4 respectively. The value of industry shipments, in constant 1972 dollars, grew at a compound annual rate of 17.2% during the period from 1972 to 1981. This growth rate declined to about 2.4% per year from 1981 to 1983,

TABLE 11-1

CLASSIFICATION OF MAJOR PRODUCTS OF INSTRUMENTS AND RELATED PRODUCTS (SIC 38)

SIC CODE	SUBDIVISION DESIGNATION AND TYPICAL PRODUCTS	% CONTRIBUTED
386	**PHOTOGRAPHIC EQUIPMENT AND SUPPLIES**	34.4
	STILL AND MOTION PICTURE CAMERAS, PHOTOCOPYING EQUIPMENT, MICROFILMING, BLUEPRINTING AND WHITEPRINTING EQUIPMENT, SENSITIZED FILM AND PLATES PREPARED PHOTOGRAPHIC CHEMICALS AND X-RAY FILM.	
382	**MEASURING AND CONTROLLING INSTRUMENTS**	27.4
	THERMOSTATS, AIR CONDITIONING AND REFRIGERATION CONTROLS, HUMIDITY INSTRUMENTS, FLOW AND PROCESS REGULATORS, NUCLEAR REACTOR CONTROLS, FLUID METERS, COUNTING DEVICES, OSCILLOSCOPES, MEASURING AND TESTING EQUIPMENT FOR ELECTRICITY AND RADIO TESTING APPARATUS.	
384	**SURGICAL, MEDICAL AND DENTAL INSTRUMENTS AND SUPPLIES**	18.0
	SURGICAL INSTRUMENTS AND SUPPLIES, OPERATING TABLES, STETHOSCOPES, BANDAGES, ORTHOPEDIC BRACES AND CANES, HEARING AIDS, PROSTHETIC APPLIANCES AND SUPPLIES, TONGUE DEPRESSORS, WHEELCHAIRS, SPACE HELMETS AND SUITS, DENTAL EQUIPMENT AND SUPPLIES, VETERINARIAN INSTRUMENTS AND APPARATUS.	
381	**ENGINEERING AND SCIENTIFIC EQUIPMENT**	6.7
	AERONAUTICAL AND AIRCRAFT FLIGHT INSTRUMENTS, SURVEYING INSTRUMENTS, DRAFTING INSTRUMENTS AND MACHINES, COMPASSES AND OTHER NAVIGATIONAL EQUIPMENT, LABORATORY APPARATUS (EXCLUDING MEDICAL), LASERS, MAP PLOTTING INSTRUMENTS AND METEOROLOGICAL INSTRUMENTS.	
387	**WATCHES, CLOCKS AND WATCH CASES**	5.5
	WATCHES, WATCH PARTS AND MOVEMENTS, CLOCKS, CLOCK MATERIALS, PARTS AND MOVEMENTS, WATCH CASES, TIMERS AND CHRONOMETERS.	
383	**OPTICAL INSTRUMENTS AND LENSES**	4.6
	OPTICAL LENSES: PHOTOGRAPHIC, MAGNIFYING, PROJECTION AND INSTRUMENT, BINOCULARS, OPTICAL GUNSIGHTS, OPTICAL MAGNIFYING INSTRUMENTS, OPTICAL MIRRORS, OPTICAL MEASURING INSTRUMENTS, TELESCOPES, PRISMS, REFLECTORS, FIBER OPTICAL DEVICES, SPECTROMETERS, CHROMATOGRAPHIC EQUIPMENT, ELECTROPHORESIS EQUIPMENT, NUCLEAR MAGNETIC RESONANCE TYPE APPARATUS AND ELECTRON PARAMAGNETIC SPIN TYPE APPARATUS.	
385	**OPHTHALMIC GOODS**	3.4
	OPHTHALMIC LENS GRINDING, EYEGLASSES, LENS AND FRAMES, CONTACT LENS, GOGGLES, AND GLASS OR PLASTIC EYES.	

SOURCES: U.S. DOC/BOC: CENSUS OF MANUFACTURES, 1977
EOP/OMB: STANDARD INDUSTRIAL CLASSIFICATION MANUAL, 1972

TABLE 11-2

SUBDIVISIONS AND CHARACTERIZATION OF THE INSTRUMENTS AND RELATED PRODUCTS INDUSTRY (SIC 38), DURING 1980, IN 1972 DOLLARS

SUBDIVISION	PERCENTAGE CONTRIBUTION	NUMBER OF EMPLOYEES (1000)	NUMBER OF ESTABLISHMENTS[a]			GROSS VALUE OF FIXED ASSETS ($/EMPLOYEE)	NEW CAPITAL EXPENDITURES ($/EMPLOYEE)	LABOR PRODUCTIVITY ($/EMPLOYEE)
			TOTAL	LESS THAN 20 EMPLOYEES	100 OR MORE EMPLOYEES			
ALL INSTRUMENTS (38)	100	616.4	7481	4942	909	10,676	1,520	25,831
ENGINEERING AND SCIENTIFIC INSTRUMENTS (381)	7	44.7	786	507	76	6,950	1,362	22,837
MEASURING AND CONTROL DEVICES (382)	28	231.8	2079	1230	328	6,947	1,243	19,652
OPTICAL INSTRUMENTS AND LENSES (383)	5	43.5	545	346	66	7,717	1,523	23,705
MEDICAL INSTRUMENTS AND SUPPLIES (384)	17	129.8	2355	1675	233	8,462	134	20,255
OPHTHALMIC GOODS (385)	3	29.4	634	479	57	7,080	489	15,995
PHOTOGRAPHIC EQUIPMENT & SUPPLIES (386)	36	114.2	780	515	94	25,396	2,838	48,739
WATCHES, CLOCKS, & WATCH CASES (387)	4	23.0	302	190	55	5,105	428	16,168

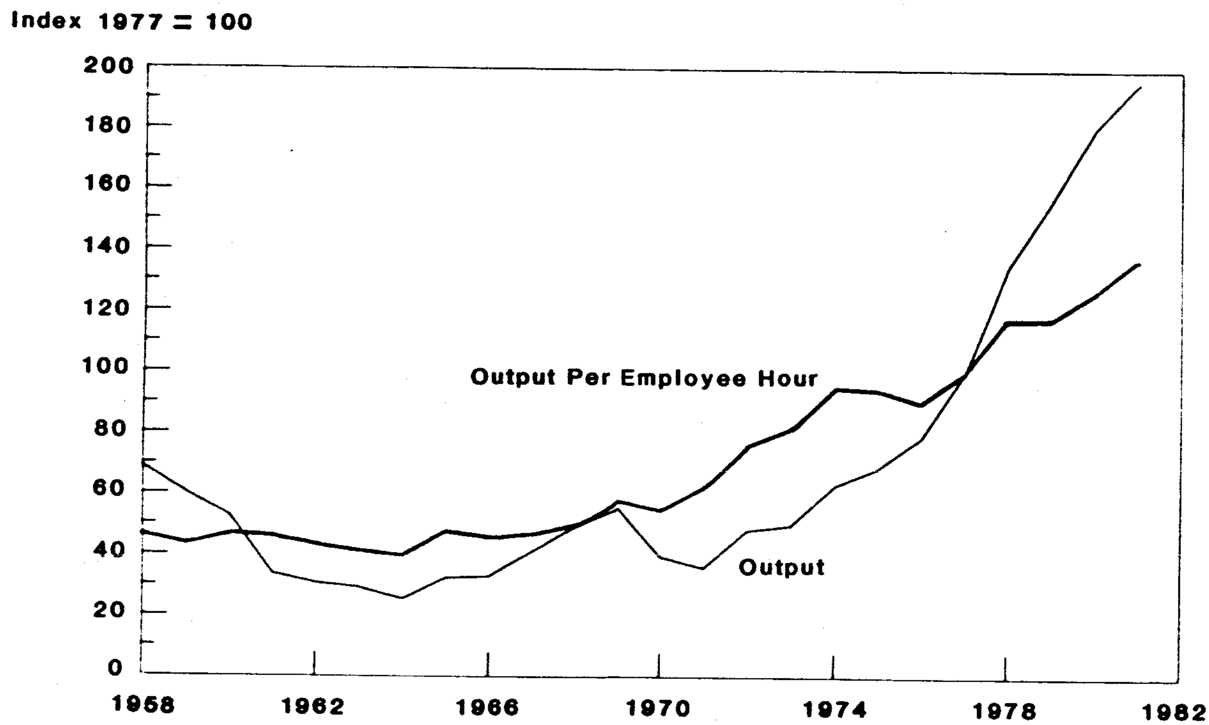
[a] 1977 DATA

SOURCES: U.S. DOC/BOC: CENSUS OF MANUFACTURES, 1977
U.S. DOC/BOC: ANNUAL SURVEY OF MANUFACTURES, 1981

TABLE 11-3

BUSINESS PROFILE OF THE OPTICAL INSTRUMENTS AND LENSES INDUSTRY (SIC 383)

SHIPMENTS (BILLION $)	1972	1977	1979	1980	1981	1982	1983
CURRENT $	0.5	1.3	2.2	2.7	3.1	3.2	—
1972 $	0.5	1.1	1.8	2.0	2.2	2.3	2.3
TOTAL EMPLOYMENT (THOUSANDS)	18.8	30.2	39.8	43.5	45.9	44.9	45.5



Source: Unpublished BLS Data

SOURCE: U.S. DOC/BIE: 1983 U.S. INDUSTRIAL OUTLOOK

TABLE 11-4

STRUCTURAL PROFILE OF THE OPTICAL INSTRUMENTS AND LENSES INDUSTRY (SIC 3832)

ESTABLISHMENTS (1977) (CATEGORIZED BY NO. OF EMPLOYEES)		LEADING FIRMS (1983) FIRM	DOMESTICALLY GENERATED SALES (MILLION $)
SMALL (<20)	346	CORNING GLASS WORKS	680
INTERMEDIATE (20-1000)	196	HARRIS CORP.	400
LARGE (>1000)	4	LITTON INDUSTRIES, INC.	370
		BAUSCH & LOMB, INC.	300
TOTAL	546	HONEYWELL, INC.	270
(APPROXIMATELY 500 COMPANIES)		GENERAL INSTRUMENT CORP.	220

	MFG LABOR	OTHER LABOR	MATERIALS	ENERGY	CAPITAL
PRODUCTION COST DISTRIBUTION, 1977	14.2%	17.5%	30.0%	4.2%	34.1%

SHIPMENTS ACCOUNTED FOR BY FOUR LARGEST COMPANIES, 1983	35%
AVERAGE ESTIMATED AGE OF PLANTS OF LEADING FIRMS, 1983	4 YEARS
NEW CAPITAL EXPENDITURES, 1981 (MILLIONS)	127

SOURCES: U.S. DOC/BIE: 1983 U.S. INDUSTRIAL OUTLOOK
U.S. DOC/BOC: CENSUS OF MANUFACTURES, 1977

and is predicted to be about 4% in 1984. The market for lasers, industrial alignment optical devices, inspection instruments, and analytical instruments showed a low growth rate in 1983. Fiber optics sales, on the other hand, are expected to continue a booming growth trend.

Structurally, the optical instruments industry (see Table 11-4) is characterized by a large number (63%) of small production establishments. Total industry employment rose 10.4% annually from 1972 to 1981, then experienced a downturn of 2.2% in 1982. Production cost distribution for optical instruments is nearly evenly divided among labor, capital, and materials. Industry standards are the major constraints on this subdivision. An additional constraint is the lack of new manufacturing and product technology information transfer within the industry. This is especially apparent in the lack of standards for the fiber optics manufacturers, a result of the high level of secrecy maintained with respect to manufacturing techniques in this fairly fragmented industry. Dominant constraints affecting this industry are summarized in Table 11-5.

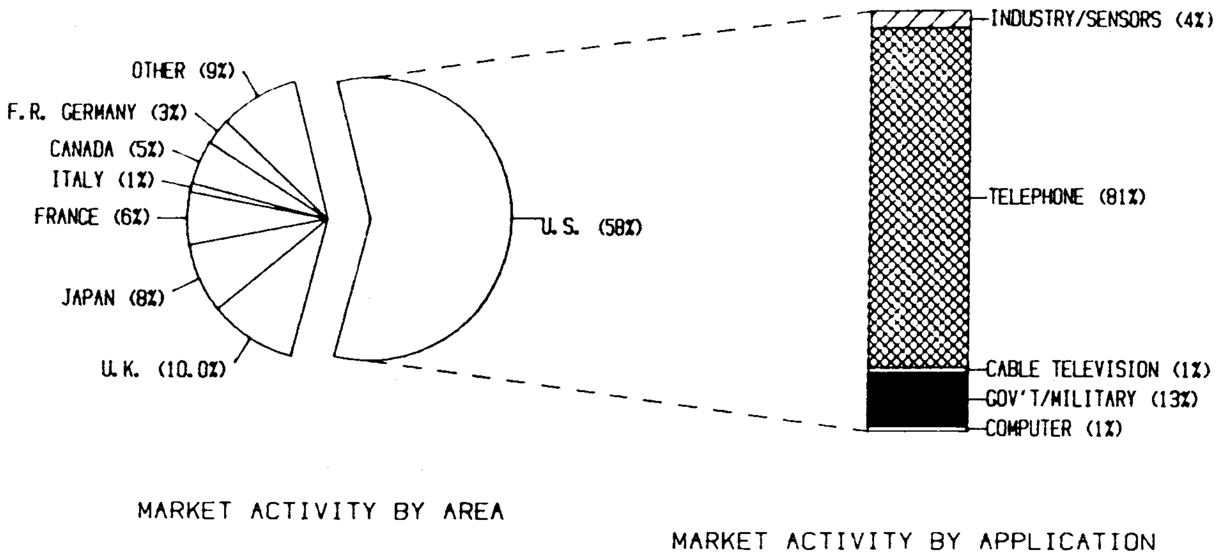
Fiber Optics and Related Devices

Fiber optics technology is expected to outstrip the rest of the optical instruments and lenses industries in terms of real growth. There are 273 firms manufacturing fiber optics in 1984 as compared to 176 firms in 1982. Of these firms, 74% are in the U.S. Between 1979 and 1981, fiber optics industry employment grew 24.5% to nearly 10,000. The additional contribution to the U.S. GDP over these two years was $84.8 million. Market figures clearly show the fast rate at which demand for optical fibers is growing. In 1975, U.S. consumption of fiber optic communications components was $2 million, while worldwide demand was $3 million. In 1983, domestic consumption of fiber optic communication components was valued at $498 million. Fiber optics market activity for 1982 is portrayed in Figure 11-1.

TABLE 11-5

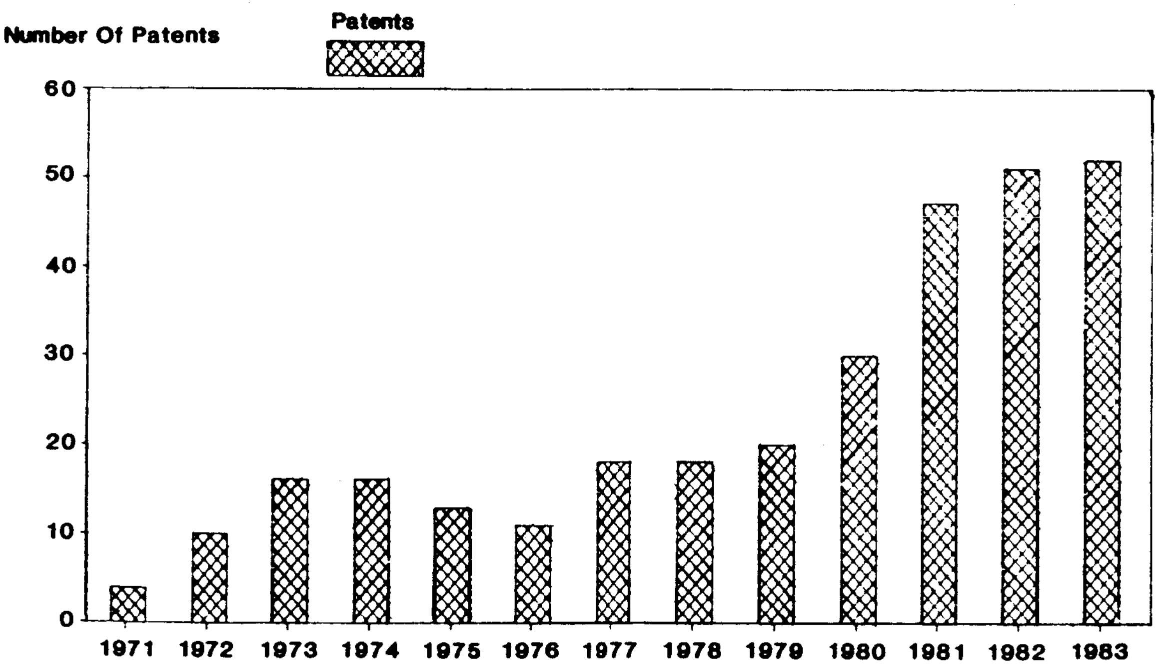
DOMINANT CONSTRAINTS AFFECTING THE OPTICAL INSTRUMENTS AND LENSES INDUSTRY (SIC 383)

MONETARY POLICY	STRONG U.S. DOLLAR ADVERSELY AFFECTS PERFORMANCE OF U.S. OPTICAL PRODUCTS IN WORLD MARKETS AND, AT THE SAME TIME, CREATES U.S. DOMESTIC MARKET OPPORTUNITIES FOR COMPETITIVE IMPORTS.
SHORTAGE OF SCIENTISTS/ENGINEERS	COMPETING FOREIGN INDUSTRIES HAVE LARGER AMOUNTS OF ENGINEERING GRADUATES THAN U.S. THIS DEFICIT MAY LEAD TO U.S. PRODUCTIVITY LAGGING BEHIND REST OF WORLD IN TERMS OF GROWTH RATES.
PATENT FEES	HIGH BASE FILING AND BASE ISSUE FEES FOR PATENTS AND ONE YEAR PENDENCY PERIOD RESTRICT INNOVATIONS.
LACK OF INDUSTRY STANDARDS	LEADS TO REDUNDANT DEVICES AND TECHNIQUES, HAMPERS INTERINDUSTRY COMMUNICATIONS.



SOURCE: OPTICAL INDUSTRY & SYSTEM PURCHASING DIRECTORY 1984 FROM THE PUBLISHERS OF PHOTONICS SPECTRA MAGAZINE

Figure 11-1. Fiber Optics Market Activity in 1982 (Installed Value)



Source: Kessler Marketing Intelligence
(As Quoted In Mechanical Engineering May 1984)

Figure 11-2. Patents Awarded for Fiber-Optic Sensor Devices During the Past Decade

The fiber optics industry has grown more rapidly than the majority of forecasts had projected. Industry growth rates of between 50% and 100% per year are projected to the end of this decade. According to one source, Gnostic Concepts, the domestic market for optical fibers is growing by 17% per year and should reach $1.87 billion by 1990 (66% of domestic production). Another current projection, from Information Gatekeepers Incorporated of Brighton, Massachusetts, predicts the 1990 optical fiber market to be valued at between $5 and $10 billion, $2.3 billion of which will be communications components. Free world consumption of fiber optics should be three times that of the U.S. domestic consumption during this same period.

One small but rapidly growing area of the fiber optics industry is sensors based on fiber optics technology. An indicator of the growth rate of this area is the number of patents issued for optic sensor devices, which have doubled since 1979 as depicted in Figure 11-2. According to Kessler Marketing Intelligence, U.S. consumption of fiber optic sensors will grow at an annual rate of 30% from $20 million in 1983, to $280 million in 1993. Another research company, Electronicast Corporation, puts the figure for the fiber optic sensor market at $736 million in 1990. Most U.S. fiber optics manufacturers (65%) employ less than 99 persons. European and Japanese firms are disproportionately represented in large manufacturing firms, accounting for 40% of the large (>1000 employees) establishments. Foreign firms account for about 20% of establishments employing less than 1000 persons in the fiber optics industry.

Competitive Issues Affecting The Optical Instruments and Lenses Industry

Exports are an important market for products manufactured by this industry, accounting for approximately 30% of product shipments. Imports amount to approximately 22% of apparent consumption of this industry's products. Exports grew at a compound annual rate of 32% from 1972 to 1982, while imports rose at a compound annual rate of 17% during this same period. The positive balance of trade rose at a compound annual rate of 27% during this ten year period.

High volume optics production continues to move to the Far East as a result of lower labor costs. U.S. production of advanced optics continues to increase as small companies find markets that are not being exploited by larger companies. One reason for the growth of these small firms is that these optics are produced in small batches that preclude economies-of-scale. Industrial items account for the major part of U.S. production, while foreign producers supply most consumer items.

Factors that would have a positive impact on U.S. exports of optical devices are revitalizing the technological base and foreign market growth. Favorable tax treatment for industry R&D plus increased military spending should contribute to technology growth. Foreign market growth would require either depreciation of the dollar, inflation increases in foreign economies as compared to the U.S., and/or improvements in foreign economic strength.

Productivity in the Optical Instruments and Lenses Industry

As shown in Table 11-4, production costs for products in this category are nearly evenly divided between capital, labor, and materials (including energy). It is apparent from the figure in Table 11-3 that the productivity (output per employee hour) has been rising steadily by around 6% per year.

Role of Technology in the Long-Term Strategic Outlook

After adjusting for inflation, the projected growth rate for the optical instruments and lenses industry is 3.9% through 1987. Beyond that point, it is difficult to predict the rate of growth for this industry. Both the military and private sectors should continue to increase their utilization of the industry's conventional products at a steady rate. These conventional products include analytical instruments such as biochemical analyzers, liquid chromatographs, amino acid analyzers, sighting and tracking optics, and infrared detectors. However, conventional products will not contribute as much to growth in the late 1980s as they did during the past decade, since their application is limited by the availability of capital for improvements. For example, although an industry that utilizes heavy equipment would find many benefits from installing an infrared detector to analyze wear of machinery components prior to actual failure, it would not feel as pressed to install this equipment as it was to install pollution analysis and control instruments following the pollution control legislation passed during the 1970s.

The fiber optics portion of the optical instruments and lenses industry will continue to grow more rapidly than the rest of the industry. Figure 11-3 illustrates the predicted growth of fiber optics production; the expected growth rate for fiber optic component markets is shown in Figure 11-4, as forecasted by Kessler Marketing Intelligence.

The largest market for optic fibers is the communications industry. The impact of technological advances in the fiber optics communications industry is provided in the "Communications Services" section of this volume. In general, advances in fiber purity are enabling the installation of larger data links with fewer repeaters than conventional copper cables. A brief summary of advances in communications fiber optics is provided Table 11-6.

The three main types of optical fibers are stepped-index multimode, graded-index multimode, and stepped-index monomode. Stepped-index fibers have a distinct transition from transparency to opaqueness. Graded index fibers gradually change their refrac-

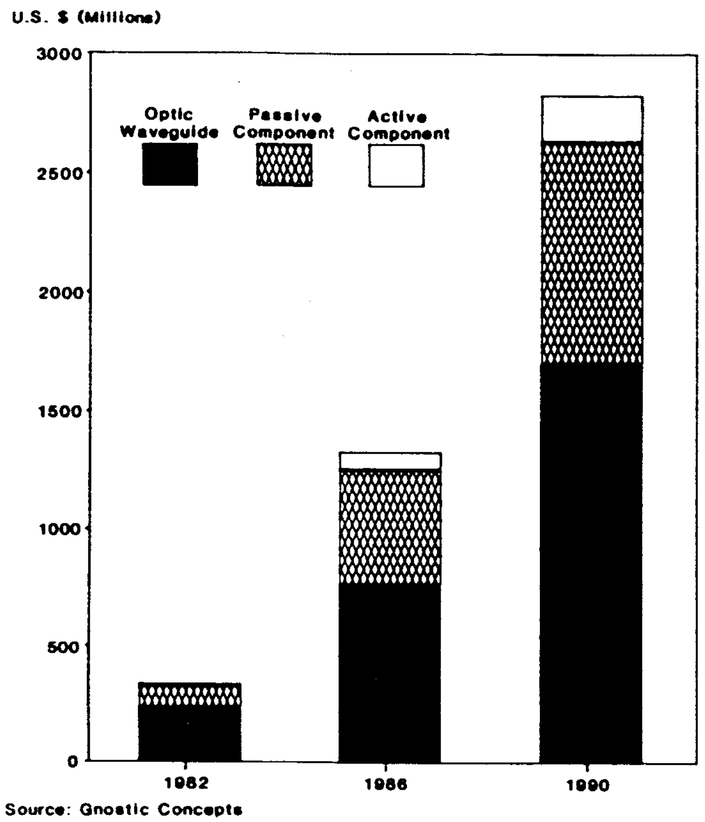


Figure 11-3. U.S. Fiber Optic Component Production to 1990

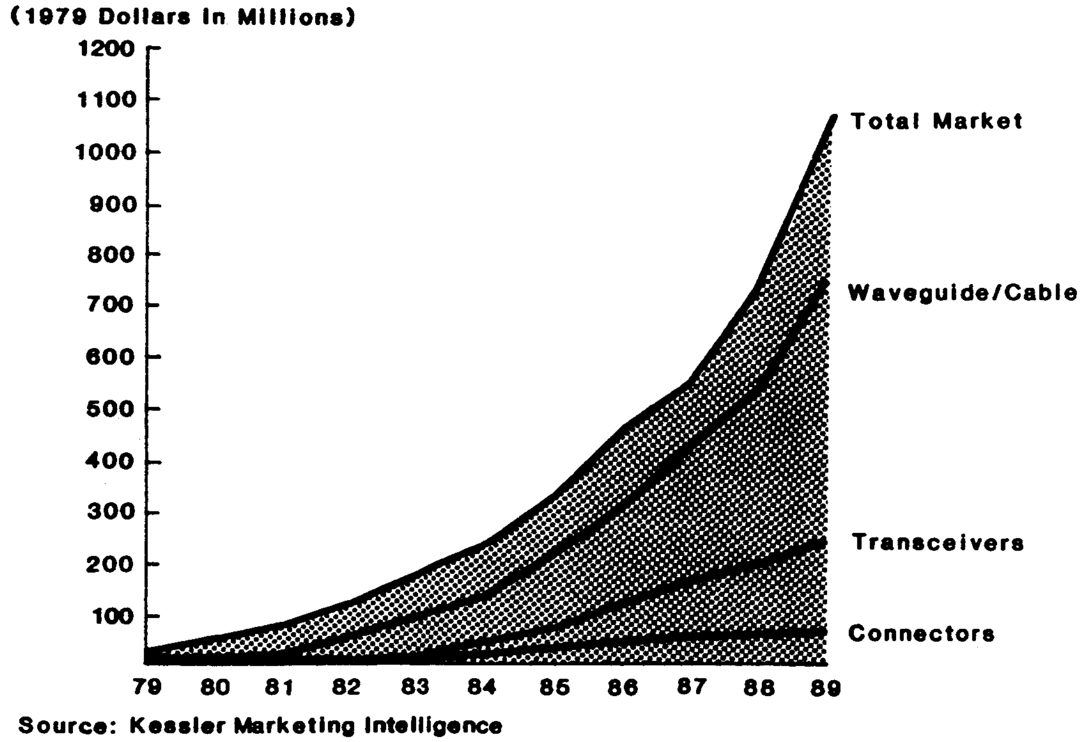


Figure 11-4. The U.S. Commercial and Industrial Fiber Optic Communications Components Market

TABLE 11-6

NEW OPTICAL INSTRUMENT TECHNOLOGIES

TECHNOLOGY	DESCRIPTION	PRINCIPAL IMPACT	APPROXIMATE ERA OF SIGNIFICANT DIFFUSION
LASERS AND OPTIC FIBERS			
• FLAT PANEL TELEVISION SCREEN	FIBER OPTIC RIBBON BIASED CUT PROVIDES CLEARER, SHARPER CONTRAST AND RESOLUTION.	REDUCE TELEVISION WEIGHT, IMPROVE RESOLUTION.	
• OPTIC FIBER THERMOMETER	FIBER WITH OPTIC CAVITY AT ONE END COATED WITH METAL WHICH EMITS LIGHT WHOSE INTENSITY IS PROPORTIONAL TO TEMPERATURE.	REPLACE THERMOCOUPLES.	
• LONG LIFESPAN LASER	LASER SOURCE FOR OPTIC TRANSMISSION IN 2-10μm BANDWIDTH WITH 6 MILLION HOUR LIFESPAN.	IMPROVE SOURCE PERFORMANCE.	
• COHERENT FIBER OPTIC TECHNOLOGY	MAKES POSSIBLE THE USE OF SIGNAL PROCESSING TECHNIQUES PRESENTLY APPLIED TO RADIO FREQUENCY CARRIERS FOR OPTICAL FIBER SYSTEMS.	IMPROVE FLEXIBILITY AND VERSATILITY OF OPTIC SIGNAL HANDLING AND PROCESSING.	
• INTEGRATED OPTO-ELECTRONICS	COMBINATION OF OPTICAL AND ELECTRONIC COMPONENTS IN STABLE, HIGH PERFORMANCE SUBSYSTEMS (OPTICAL SOURCES AND DETECTORS COUPLED WITH ELECTRONIC SIGNAL GENERATION, MODULATION, AMPLIFICATION, DETECTION, SWITCHING, AND FILTER CIRCUITS).	EASES INTERCONNECTION PROBLEMS, STABLE STRUCTURE NECESSARY FOR VERSATILE CONFIGURATIONS.	
NONINVASIVE DIAGNOSTICS			
• COMPUTER AXIAL TOMOGRAPHY (CAT, CT)	INSTRUMENT CONFIGURATION IS A CIRCULAR SCANNER GANTRY CONSISTING OF AN X-RAY TUBE WITH DETECTORS MOUNTED OPPOSITE IT AND A CENTRAL APERTURE WITH A RADIOTRANSLUCENT TABLE FOR THE PATIENT TO LIE ON. GANTRY ROTATES 360° AROUND PATIENT WHILE DATA ARE STORED IN COMPUTER MEMORY.	AN IMPROVEMENT ON X-RAY TECHNOLOGY-COMPUTER ENHANCEMENT OF X-RAY IMAGES PROVIDING BETTER DIAGNOSTIC INFORMATION.	
• NUCLEAR MAGNETIC RESONANCE (NMR)	A LARGE CIRCULAR GANTRY SURROUNDS PATIENTS, WITH THE AXIS OF THE GANTRY CENTERED ON THE LONG AXIS OF PATIENT. GANTRY HOUSES COILS TO PRODUCE STRONG STATIC AXIAL MAGNETIC FIELD, COILS TO PRODUCE GRADIENTS IN THIS FIELD, AND AN R-F COIL TO TRANMIT EXCITORY PULSES (LARMOR FREQ.) AND PICK UP THE NMR SIGNAL WHEN A SHORT R-F PUSLE AT THE LARMOR FREQUENCY IS APPLIED TO NUCLEI EXPERIENCING NET EQUILIBRIUM NUCLEAR MAGNETIZATION, THE SPINS OF THE NUCLEI ARE MADE TO PRECESS, AND THE RESULTANT INDUCED EMF AT THE LARMOR FREQUENCY IS DETECTABLE.	ALLOWS TOMOGRAPHIC SCANNING WITHOUT IONIZING RADIATION THEREFORE REDUCING PATIENT RISK. PRODUCES CHEMICAL AS WELL AS DIAGNOSTIC DATA. PRODUCES UNOBSTRUCTED IMAGES IN BOTH CROSS-SECTION AND SAGGITAL PLANE VIEWS.	

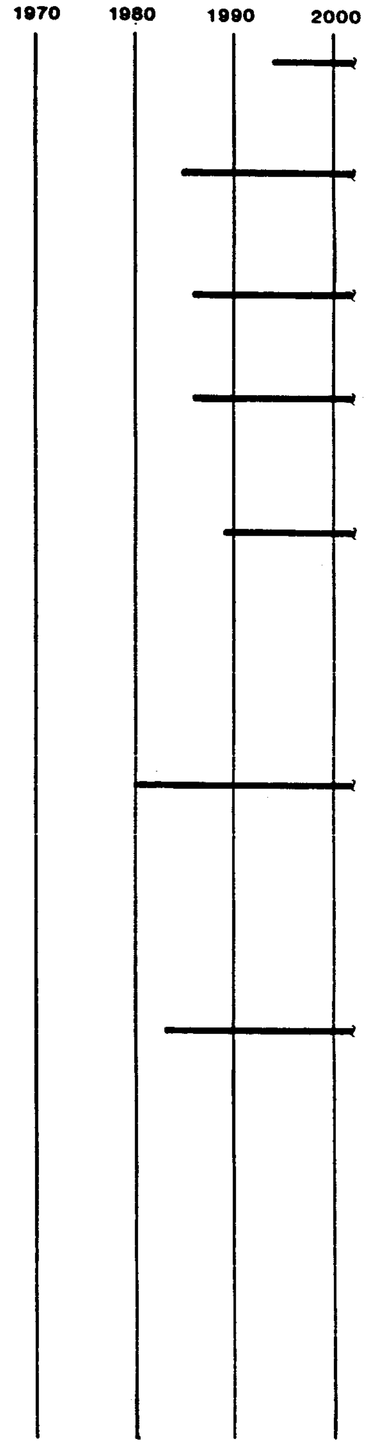


TABLE 11-6 (CONTINUED)

NEW OPTICAL INSTRUMENT TECHNOLOGIES

TECHNOLOGY	DESCRIPTION	PRINCIPAL IMPACT	APPROXIMATE ERA OF SIGNIFICANT DIFFUSION (1970, 1980, 1990, 2000)
• POSITRON EMISSION TOMOGRAPHY (PET)	PET CONSISTS OF DISCRETE SCINTILLATORS ARRANGED IN RINGS (100 DETECTORS PER RING, 5 RINGS PER GANTRY) THAT DETECT HIGH ENERGY (511 KEV) PHOTONS EMITTED WHEN POSITRONS FROM POSITRON EMITTING ISOTOPES INJECTED INTO THE PATIENT ANNIHILATE ELECTRONS (PHOTOELECTRIC EFFECT).	DEVELOPED IN THE 1970s. UTILIZES ISOTOPE INJECTION COMBINED WITH COMPUTER ASSISTANCE TO MEASURE AND VISUALIZE HUMAN METABOLISM. IMPROVED VERSIONS CAPABLE OF DETECTING RAPID CHANGES IN METABOLISM.	
• DIGITAL SUBSTRUCTION	INCORPORATES FLOUROSCOPY AND ANGIOGRAPHY INTO CT SCANNING TO PROVIDE MORE DIAGNOSTIC INFORMATION IN A SINGLE SCAN.	PROVIDES MORE INFORMATION PER SCAN-MORE DETAILED DATA THAN X-RAY.	
• ULTRASOUND SCANNERS (US)	UTILIZES SHORT PULSES OF UTRA-HIGH FREQUENCY ACOUSTIC WAVES IN AN ECHO-RANGING SYSTEM TO MAP TISSUE CHARACTERISTICS WITHIN THE BODY.	PRODUCES COMPUTER ASSISTED HIGH RESOLUTION, REAL TIME IMAGES. NEW TECHNIQUES ALLOW DETECTION OF CHANGES IN TISSUE PROPERTIES INDICATING SPECIFIC DISEASES. LESS INVASIVE OF ALL BUT NMR, AND COST THAT IS A FRACTION OF OTHER METHODS COSTS.	

tive index toward opaqueness with increasing distance from the center of the core. Monomode fibers have a very small diameter center core along which only one signal can travel. Multimode fibers can accommodate more signals, but, since these signals may overlap because of the different angles at which they are injected in the fiber, multimode fibers are better suited for shorter distance communications than are monomode fibers.

Two key advantages of fiber optic transmission links when compared to conventional metal cables are the very low signal attenuation and the very low dispersion (high bandwidth) of the signal. Typical multimode fiber optic links are now running from 8 to 15km without repeaters at 850nm and up to 20-30km at the 1300nm wavelength. Lab tests have demonstrated monomode fibers operating at 1550nm for distances up to 100km without repeaters. Central office trunking networks utilizing multimode fibers have demonstrated an attenuation of 2.7 to 3.5dB per kilometer at 850nm and 1.0 to 1.5dB per kilometer at 1300nm with bandwidths from 400 to 800MHz per kilometer. State of the art monomode fibers demonstrate an attenuation of less than 1dB per kilometer at 1300nm and a bandwidth greater than 1GHz per kilometer. The price-performance advantages of fiber optic communications are demonstrable for high density trunk applications at data rates above 34 megabytes per second.

The fiber optics sensor industry is an outgrowth of the development of pure optic fibers as used for communications. Researchers investigating the effects of adverse environments on signal transmission discovered that these effects could be measured using optic fibers for sensors and coupling them with digital computers. The result of this research is a rapidly expanding field of sensors based on optical fibers.

There are two basic types of optic fiber sensors. Both have common characteristics; namely the use of a light source to inject continuous light signals into the fiber, a light detector that receives the light signals after they have been changed or modulated, and signal processing circuits. The first type of sensor uses fiber optics to access remote locations containing devices or parameters that can be optically measured; the second type relies on changes in light propagation properties of the glass fibers themselves as a result of changes in the parameters being measured. Two subdivisions of the first type are sensors that transmit light to an adapted available sensor (for instance, a motion sensor based on a moving spot painted on a mechanical lever), and sensors that use the optic fiber to transmit light to and from an optical sensor measuring such effects as light scatter. Two subgroupings of sensors that utilize changes in the physical parameters of the optic fiber are based on measuring changes in the signal's amplitude or on phase changes in the signal. Amplitude changes in the signal result from flexing, bending, or surface effects of the optical fiber. Phase changes result from strain on the fiber or changes in the fiber's length.

An optical fiber-based thermocouple has been developed that operates at 2000°C, 500°C higher than the present thermocouple standard. This sensor utilizes an optic fiber, the tip of which is coated with a metal (iridium) that emits an intense light composed of many wavelengths. A light detector measures the intensity of the light signal in a narrow bandwidth where the intensity is proportional to the temperature. This fiber may eventually replace the ANSI Type S thermocouple developed in 1886.

There are many other applications of fiber optics. Some of these are in liquid level sensors, gyroscopes, chemical analyzers, acoustic microphones and hydrophones, voltage sensors, current sensors, and as optical sensors for monitoring remote, hazardous environments such as combustion chambers, nuclear reactors, reaction vessels, etc. Besides all of the potential applications, there are several advantages that make optic fibers especially desirable; particularly when considering potential sensor applications. The advantages of optical fibers as sensors and transmission links in comparison with electrical circuits, sensors, and cables are:

- no crosstalk between cables,
- immunity to RFI/EMI/noise,
- total electrical isolation,
- no spark or fire hazard,
- no short-circuit loading,
- light weight,
- speed,
- no danger of short-circuit if wet,
- inert to explosion,
- high sensitivity,
- reliable and rugged,
- low signal attenuation, and
- difficult to tap without discovery.

Summary

The U.S. optical and analytical instrument industry is best suited to exploit the leading edge of optics technology. High volume production of optical instruments and equipment has moved offshore to countries better able to apply an economy-of-scale to production. U.S. companies are primarily engaged in producing low volume, high value precision and engineering optical goods. Growing military markets as well as the increasing use of fiber optics ensures a healthy future for this industry.

B.11.2 SURGICAL, MEDICAL AND DENTAL INSTRUMENTS AND SUPPLIES (SIC 384)

The surgical, medical and dental instruments subdivision (SIC 384) consists of establishments primarily engaged in the manufacture of medical and surgical (SIC 3841), and dental instruments (SIC 3843). Other supplies produced by this subdivision, categorized under SIC 3842, include prosthetics, orthopedic devices, artificial teeth, dental metals, bandages, surgical dressings, sutures, and personal safety equipment. X-ray and other electric diagnostic instruments are not included under this subdivision classification, nor are dentures and other dental restorations supplied by labs on a dentist's specifications.

The business profile of the medical and dental instruments and supplies industry is summarized in Table 11-7. The compound annual growth rate of shipments, in constant 1972 dollars, was 7.5% per year from 1972 to 1984; employment grew at a rate of 5% per year during this same period. There were no major downturns for these rates during this period. The growth rates for both shipments and employment slowed from 1981 to 1983, but are expected to return to the growth rates of the 1970s.

As advanced electronics are continually incorporated into medical and dental equipment, especially in diagnostic equipment, the cost of this equipment decreases while the capabilities expand. The demand has offset the decreasing cost of the equipment because of the growing proportion of the population over 65 and the fact that the new equipment is making the older models obsolete. For example, nuclear magnetic resonance (NMR) imaging equipment was developed to partially replace the more detrimental x-ray machine.

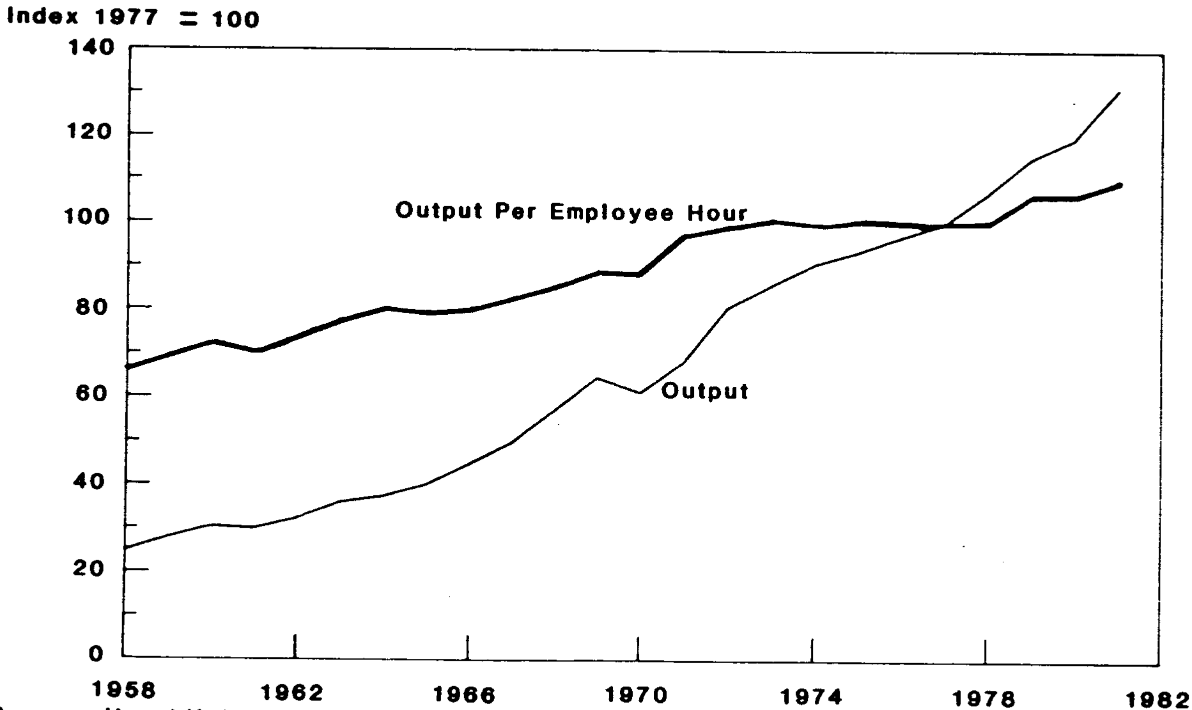
The structural profile of the medical and dental equipment industry is portrayed in Table 11-8. The two largest companies accounted for about 35% of industry shipments in 1983, while the total share of industry shipments by the five largest companies was approximately 50%. The majority of production establishments (70%) employ less then twenty employees.

Figure 11-5 illustrates the breakdown of subdivision shipments by industry. It is evident that surgical appliances and supplies (SIC 3842) is the largest and fastest growing industry subdivision in terms of shipments.

TABLE 11-7

BUSINESS PROFILE OF THE MEDICAL AND DENTAL INSTRUMENTS AND SUPPLIES INDUSTRY (SIC 384)

SHIPMENTS (BILLION $)	1972	1977	1979	1981	1982	1983 EST	1984 EST
CURRENT DOLLAR	2.82	5.22	6.78	9.21	10.16	11.36	12.88
1972 DOLLAR	2.82	3.49	4.00	4.58	4.76	5.01	5.35
TOTAL EMPLOYMENT							
THOUSANDS	90.8	113.4	124.8	136.9	138.2	141.2	146.6



Source: Unpublished BLS Data

ESTIMATED AVERAGE PLANT AGE, LEADING FIRMS, 1983 — 4 YEARS

NEW CAPITAL EXPENDITURES, IN 1981, MILLION $ — 393.2

MAJOR TRADING PARTNERS, 1982

U.S. EXPORTS		U.S. IMPORTS	
CANADA	14%	F.R. GERMANY	32%
JAPAN	10%	JAPAN	18%
F.R. GERMANY	8%	NETHERLANDS	6%
U.K.	8%	U.K.	6%
FRANCE	6%	CANADA	5%

SOURCES: U.S DOC/BIE: 1984 U.S. INDUSTRIAL OUTLOOK
U.S. DOL/BLS

TABLE 11-8

STRUCTURAL PROFILE OF THE MEDICAL AND DENTAL INSTRUMENTS AND SUPPLIES INDUSTRY (SIC 384)

ESTABLISHMENTS (1977) (CATEGORIZED BY NO. OF EMPLOYEES)		**LEADING FIRMS (1983)** NAME	DOMESTICALLY GENERATED SALES (MILLION $)
SMALL (<20)	1,675	JOHNSON AND JOHNSON	2100
INTERMEDIATE (20-1000)	664	BAXTER TRAVENOL	1840
LARGE (>1000)	14	BECTON, DICKENSON, & CO.	950
		C.R. BARD, INC.	397
TOTAL (2098 COMPANIES)	2,353	MEDTRONIC, INC.	353
		AMERICAN STERILIZER	279
		INTERMEDICS, INC.	206

PRODUCTION COST DISTRIBUTION, 1977	MFG LABOR	OTHER LABOR	MATERIALS	ENERGY	CAPITAL
	13.7%	11.5%	38.0%	1.0%	35.8%

SHIPMENTS ACCOUNTED FOR BY FOUR LARGEST COMPANIES, 1983 35%

SOURCES: U.S. DOC/BOC: CENSUS OF MANUFACTURES, 1977
U.S. DOC/BIE: 1984 U.S. INDUSTRIAL OUTLOOK
VALUE-LINE INVESTMENT SURVEY, 1984

Dominant constraints affecting the medical and dental instruments and accessories industry are summarized in Table 11-9. The primary constraint on new technologies being incorporated in new medical instruments is government regulations. Although the strong dollar and price pressures are reducing the profit margin, demand will continue to grow, regardless of equipment price.

Competitive Posture of the Medical and Dental Instruments and Supplies Industry

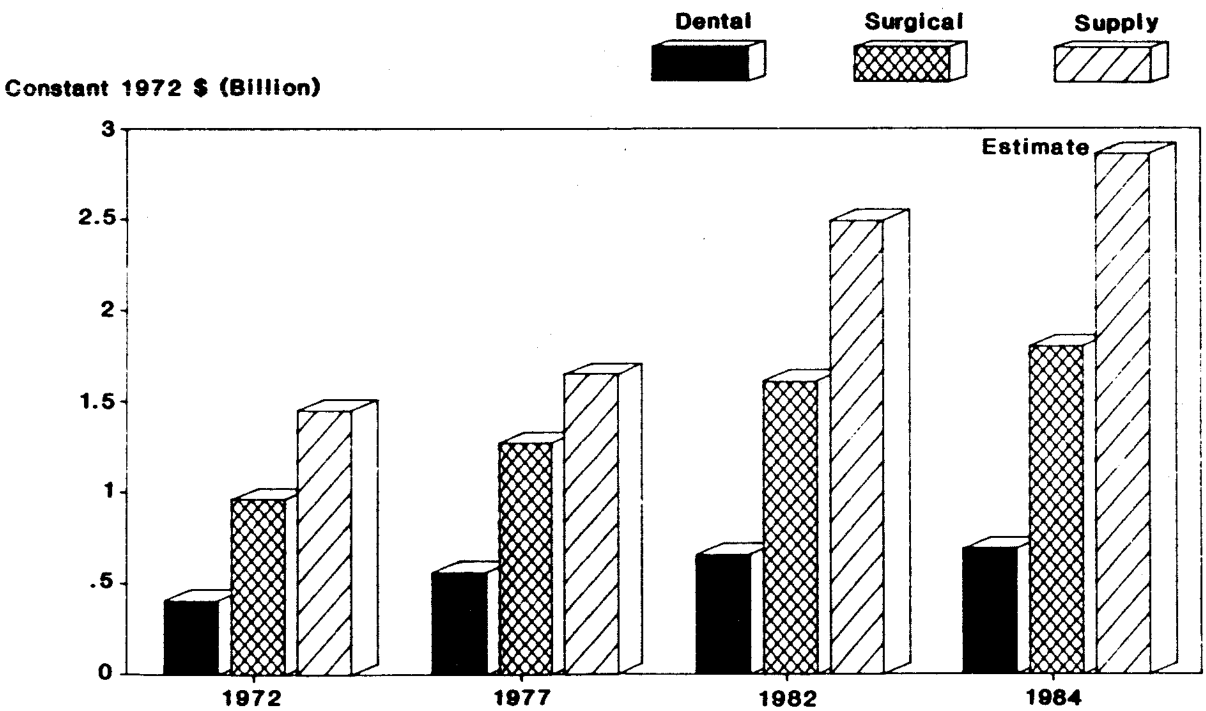
The American medical and dental equipment industry has been fairly competitive in the world market. U.S. exports of its products grew at a compound annual rate of 14.7% between 1972 and 1983. U.S. imports of medical and dental instruments and accessories grew at a compound annual rate of nearly 20% during the same period. In 1982, the U.S. maintained a positive trade balance of $744 million, which grew at an annual compound rate of 14.3% during the 1972 to 1982 period. This trade balance decreased 3.9% from 1982 to 1983, registering the first decline in over a decade. Factors contributing to this recent poor U.S. export performance are the high value of the dollar, depressed foreign markets, reduced availability of foreign capital expenditures, and increasing Japanese and European competitiveness in the medical and dental instruments industry.

Major U.S. trading partners in 1982 are listed in Table 11-7. The European Economic Community (EEC) accounted for 52% of U.S. imports of medical and dental equipment, while consuming 37% of U.S. exports. The only trading partner with whom the U.S. has a trade deficit in medical equipment is F.R. Germany. In 1983 this deficit was $43.6 million, a 38% rise over the 1982 deficit. West German imports have performed well in U.S. markets as a result of their reputation for excellent precision manufacturing. The U.S. has realized a trade surplus with Japan, but during the

TABLE 11-9

DOMINANT CONSTRAINTS AFFECTING THE MEDICAL AND DENTAL EQUIPMENT AND SUPPLIES INDUSTRY (SIC 384)

GOVERNMENT REGULATIONS	1976 MEDICAL DEVICE ACT: DEFINES CONSTRAINTS CONCERNING MEDICAL DEVICES THAT COULD KILL OR INJURE HUMANS. CONGRESS REAPPLIED PRESSURE ON FDA TO INSURE COMPLIANCE IN MAY, 1983. 1983 SOCIAL SECURITY AMENDMENTS: LIMITED AMOUNT OF MONEY THAT GOVERNMENT WILL PAY FOR DIAGNOSIS RELATED AILMENTS OF MEDICARE PATIENTS.
MONETARY POLICY	STRONG DOLLAR ADVERSELY AFFECTS PERFORMANCE OF U.S. MEDICAL INSTRUMENTS AND ACCESSORIES IN WORLD MARKETS.
PRICE PRESSURES	CONTINUED EFFORTS TO CONTAIN OR LIMIT HOSPITAL COSTS AND GROWING MULTI-HOSPITAL AND GROUP PURCHASING PLANS ARE REDUCING PROFIT MARGINS



Source: Bureau of the Census

Figure 11-5. Medical and Dental Instruments and Supplies Value of Shipments by Industry Subdivision

past five years Japan's medical exports to U.S. grew at a compound annual rate of 23%, while the U.S. exports to Japan grew at an annual rate of only 16% during the same period. The continued strength of the U.S. dollar has provided extra import potential for competitively priced Japanese and EEC goods.

Productivity in the Medical and Dental Instruments and Supplies Industry

The largest proportion of production costs, 38%, is spent on materials. The next largest portion, nearly 36%, is capital-related. Labor accounts for the remaining 25% of production costs, excluding energy, which accounts for only 1%. Although labor costs rank third in production costs, industry employment is expected to rise at an average annual rate of 4.3%, the highest rate of all manufacturing industries. Because of the diversity of products produced by this industry, it is difficult to identify trends in materials savings or capital expenditures. Since most production establishments employ less than twenty people and produce highly specialized products, economy-of-scale may not apply to most of this industry.

Role of Technology in the Long-Term Strategic Outlook

The five year forecast for this industry predicts a sustained average annual growth rate of about 6% (adjusted for inflation) in industry shipments. Employment should also continue to grow approximately 4% annually. Demand for medical and dental equipment will rise from new medical school graduates and as a result of increasing home health care. New materials and more sophisticated electronics will continue to be incorporated in conventional devices as well as in new applications. The strong performance of medical and dental equipment and supplies in both domestic and overseas markets, as well as the increasing demand for more advanced equipment, result in an industry with "sunrise" tendencies. The largest industry within the subdivision, surgical equipment and supplies (SIC 3842), will grow the most rapidly of all medical and dental equipment industries, at a rate of 6.8% during the next five years.

Technologically advanced product innovations in this industry are based on new materials and computer technology. Advances in prosthetics already include computer-controlled electric actuators that respond to impulses in the stump nerve. It is now standard procedure to replace human joints. Biocompatible implant materials are improving in strength and durability, which leads to longer amounts of time between implant replacement. Some devices producing artificial sight and hearing are now being tested with human subjects. R&D of the fully implantable artificial heart is also progressing and may be in widespread use in a decade.

The surgical instruments industry (SIC 3841) is the second largest industry of the medical and dental instruments and supplies subdivision; it is also second in rate of growth at 5.8% per year. Exciting developments are resulting from new surgical instruments. Fiber optics have enabled endoscopy, or very limited incision surgery, to be developed. Endoscopy reduces hospital stays by enabling faster healing and by removing or repairing only the damaged tissue on a near microscopic level. Fiber optics technology has also made the laser scalpel possible.

New technologies in the dental equipment and supplies industry (SIC 3843) are improving dentist and assistant productivities while reducing patient discomfort. Tools are lighter and incorporate new features for drilling, cleaning, and polishing. Fiber optic lighting devices are reducing dentist workload while improving accuracy. New chair designs are more comfortable for the patient.

Summary

Generally, new medical and dental equipment is incorporating computer technology to enhance the speed, image clarity, and analytical capabilities of patient monitoring systems. In order to offset new equipment costs experienced by hospitals, equipment manufacturers are incorporating multifunction capabilities into their new equipment designs. Researchers have demonstrated the ability to construct miniature analytical sensors on silicon. There are a variety of applications, currently limited by cost, for which these sensors may find use. Table 11-10 summarizes technology trends for the medical and dental equipment and supplies industry. A more in depth review of these new techniques may be found in Sections C.1 and E.6.

B.11.3 THE PHOTOGRAPHIC EQUIPMENT AND SUPPLIES INDUSTRY (SIC 386)

This industry consists of establishments involved in manufacturing all types of photographic equipment, such as still and motion picture cameras and projection apparatus and accessories, sensitized film paper, cloth, plates and prepared photographic chemicals. It also includes photocopy and microfilm equipment as well as blueprinting and diazotype apparatus.

One of the strengths of this industry is the production of a wide variety of products that serve a number of broad end-user markets. The consumer market includes products for amateur use; such as cartridge and instant cameras, film, and accessories. The business and industrial markets cover film processing equipment, photocopying and microfilming equipment and supplies, and cameras and accessories for professional and industrial applications. Because of this wide-range of products, manufacturers have found markets with a sufficient demand to allow moderate growth despite recent poor economic conditions. The average annual growth rate from 1972 to 1983 for this industry was 5.3%.

TABLE 11-10

NEW MEDICAL INSTRUMENT TECHNOLOGIES

TECHNOLOGY	DESCRIPTION	PRINCIPAL IMPACT
CURATIVE TECHNOLOGY		
● HELIUM BEAM RADIATION	CAPABLE OF DELIVERING 8,000 RADS TO A TUMOR WITH PRECISIONS SUCH THAT TISSUE 3mm FROM POINT OF FOCUS IS UNAFFECTED.	REDUCES TRAUMA ASSOCIATED WITH SURGERY BY REDUCING DAMAGE TO HEALTHY TISSUE SURROUNDING PROBLEM SITE.
● COLD FIRE LASER SURGERY	EXCISION OF ABNORMAL GROWTHS, SELF CAUTERIZATION OF INCISIONS, DESTRUCTION OF CANCEROUS CELLS, ADAPTABLE TO OUTPATIENT TREATMENT. IN ADDITION, PROVIDES A FINER CUTTING LINE, USED NOW AS PHOTOCOAGULATOR, OR FOR REATTACHMENT OF OPTIC NERVE TO RETINA. ULTRA-VIOLET LASERS (UV) OR COLD LASERS DISRUPT THE BINDING CELL ENERGY WITHOUT AFFECTING NEARBY CELLS.	REDUCES DAMAGE TO HEALTHY TISSUE COMPARED TO CONVENTIONAL SURGERY, EASES HEALING PROCESS.
● MICROWAVE SCALPEL	HIGH FREQUENCY VERSION OF RADIO FREQUENCY DEVICES WITH LESS CELL DISRUPTION.	REDUCED DAMAGE TO HEALTHY TISSUE COMPARED TO CONVENTIONAL SURGERY.
● PUMP APHERESIS	WILL DRAW, SEPARATE, TREAT, FILTER AND RETURN THE BLOOD. CURRENTLY UNDER RESEARCH WITH APLASTIC ANEMIA AND LUPUS.	ALLOWS USE OF CHEMICALS TO TREAT BLOOD COMPONENTS OUTSIDE OF THE BODY THAT WOULD BE IMPOSSIBLE OTHERWISE.
● ENDOSCOPICS	USING FIBER OPTICS, USED FOR ILLUMINATION, VIEWING, SALINIZATION, OR FLUID/PARTICLE WITHDRAWAL IN BIOPSYS AND MICROSURGERY. REDUCES PERFORMANCE TIME AND COSTS, HOSPITAL STAYS AND LOSS OF WORK TIME.	REDUCES SIZE AND AMOUNT OF INCISIONS, ESPECIALLY FOR DIAGNOSTIC SURGERY. REDUCES PERFORMANCE TIME AND COSTS, HOSPITAL STAYS AND RECOVERY TIME.

APPROXIMATE ERA OF SIGNIFICANT DIFFUSION

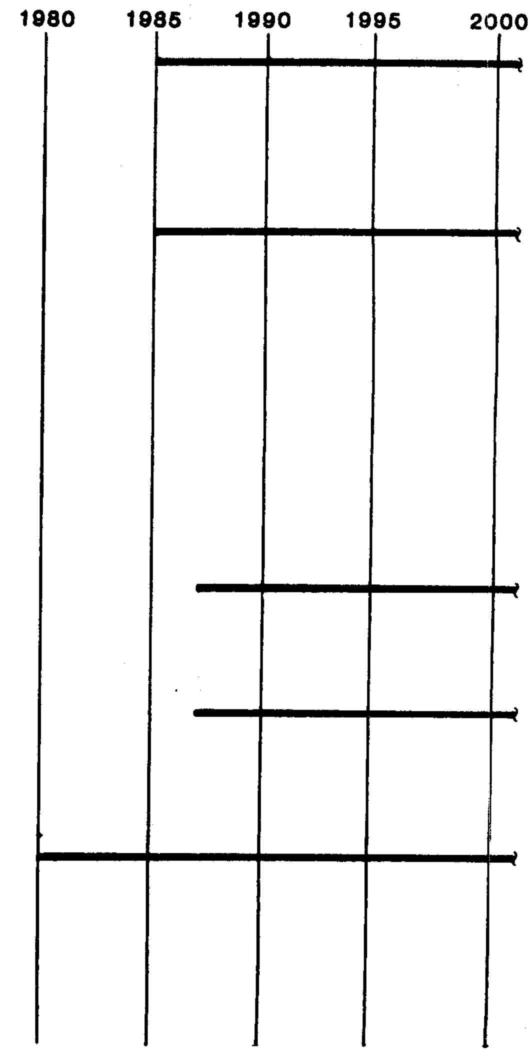


TABLE 11-10 (CONTINUED)

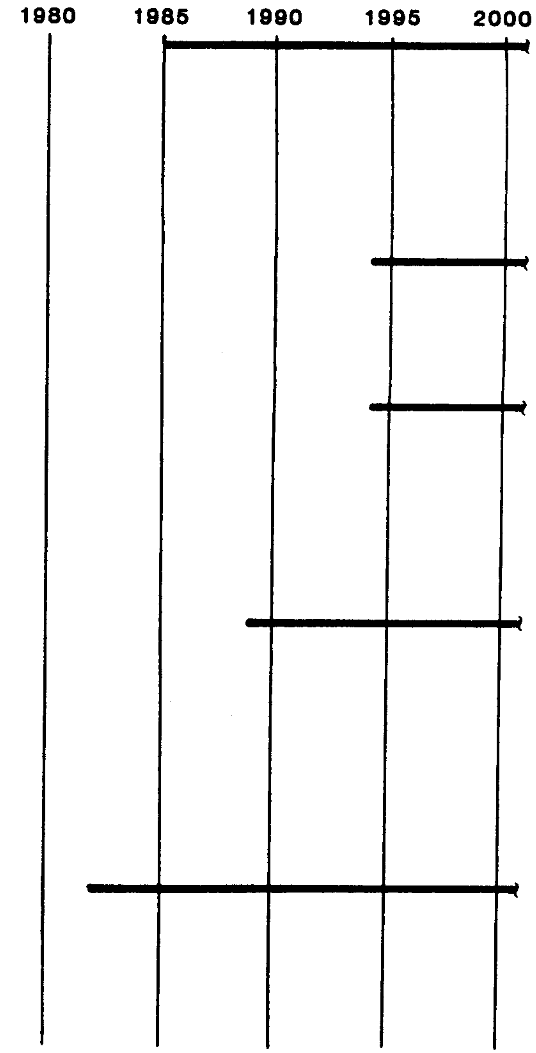
NEW MEDICAL INSTRUMENT TECHNOLOGIES

TECHNOLOGY	DESCRIPTION	PRINCIPAL IMPACT	APPROXIMATE ERA OF SIGNIFICANT DIFFUSION 1980 1985 1990 1995 2000
A) TRANSDUCER HEADS	TO MEASURE CHEMICAL IN-BALANCES, CELLULAR FLUIDS, AND CHEMICAL INDICATORS, WOULD ALLOW PARALLEL EN-DOSCOPIC AND REMOVAL OF DISEASED/DAMAGED CELLS, WOULD REDUCE MENTAL/PHYSI-CAL TRAUMA, DECREASE RISK OF INFECTION, ELIMINATE NEED FOR TRANSFUSIONS, RE-DUCE HOSPITAL STAYS.	ENABLES IMMEDIATE DIANOSIS AND REMOVAL OF DAMAGED CELLS WHEN COUPLED WITH OTHER EN-DOSCOPIC SURGERY. ALL OTHER ADVANTAGES OF ENDOSCOPICS APPLY TO THIS TECHNOLOGY, TOO.	
B) SUTURING HEADS	BIODEGRADABLE SNAPRINGS ATTACHED IN SUTURING HEAD TO "CLAMP" TISSUE TO-GETHER.	EASES SURGICAL WORKLOAD, DIRECTLY EMPLOYABLE FOR ENDOSCOPICS.	
C) ADHESIVE AUGMENTED PLASTIC SUTURES	ALSO BIODEGRADABLE TO AUGMENT OR SUBSTITUTE FOR PLASTIC SUTURES.	EASES SURGICAL WORKLOAD, COMPATIBLE WITH ENDO-SCOPICS	
● INTRA-ARTERY BALLOONS	BALLOONS INSERTED IN MAIN VESSELS AND ARTERIES AROUND SURGICAL SITE.	REDUCES THE NEED TO LIGATE VESSELS OR PRO-VIDE REPLACEMENT BLOOD.	
● COMPUTERIZED ANESTHESIOLOGY (GAS PASSERS)	COMPUTERIZED ANESTHESIOLOGY WHICH ALSO MONITOR VITAL SIGNS, BLOOD GASES, AIRWAY RESISTANCE AND INDUCED GAS CONCENTRATION.	REDUCE SURGICAL TEAM WORKLOAD, EVENTUALLY REPLACE ANESTHETIST WITH ROBOT.	
NEW MATERIALS PROSTHESIS			
● ARTIFICIAL ORGAN TECHNOLOGY ARTIFICIAL HEART	NEW NONREACTIVE MATERIALS AND THE DEVELOPMENT OF MINIATURIZED PROPULSION SYSTEMS AND POWER SOURCES.	REDUCE MORTALITY RATE FROM CORONARY AILMENTS.	
● ARTIFICIAL LIMB PROSTHESIS	NEW ADVANCES IN SENSORS, MINIATURE MOTORS, POWER SUPPLIES AND LIGHT ALLOY MATERIALS WILL IMPROVE UTILITY, ALLOW FINE MANI-PULATIONS AND PRODUCE AESTHETICALLY ENHANCED PROSTHETICS.	IMPROVE UTILITY AND ALLOW FINE MANIPULATIONS.	

TABLE 11-10 (CONTINUED)

NEW MEDICAL INSTRUMENT TECHNOLOGIES

TECHNOLOGY	DESCRIPTION	PRINCIPAL IMPACT	APPROXIMATE ERA OF SIGNIFICANT DIFFUSION
● ARTIFICIAL SKIN	CHEMICALLY SYNTHESIZED FROM ANIMAL HIDES, PROVIDES AN ORGANIC BUT BIOLOGICALLY INERT COVER FOR BURN VICTIMS. IS ABSORBED BY THE BODY DURING THE HEALING PROCESS. REDUCES SCARRING.	GREATLY INCREASE RECOVERY RATES FOR BURN VICTIMS.	
● ARTIFICIAL BLOOD	TEFLON BASED WITH AN ARTIFICIAL HEMOGLOBIN, CAN BE USED IN TRANSFUSIONS WITHOUT CROSS-MATCHING.	REPLACE BLOOD VOLUME WITHOUT USING REAL BLOOD RESERVES.	
● ARTIFICIAL BODY COMPONENTS	THROUGH GENETIC AND MOLECULAR ENGINEERING. TREATMENTS FOR DEGENERATIVE DISEASES. OSTEOPOROSIS AND REPLACEMENT PROSTHESIS, BY COMPUTER DESIGN, WILL PROMOTE BONY INGROWTHS, AND JOINT REMODELING.	REGENERATE TISSUE OR REPLACE DEFECTIVE PARTS.	
● NEUROMUSCULAR STIMULATORS	REPLICATION OF NERVE CELLS OR SYNTHETIC NERVE CELLS TO COMPLIMENT EXISTING CELLS. IMPLANTATION OF "JUMP WIRES" TO REPAIR FAULTY NEUTRAL CONDUCTION PATHWAYS (WITH OUTSIDE-BODY POWER SOURCE). TIMING UNITS OR BIOLOGICAL SWITCHES WILL PERIODICALLY POLARIZE ITSELF.	REGENERATE TISSUE, ENABLE OR SPEED UP HEALING.	
● LIMB TRANSPLANTS	COMBINING JOINT RECONSTRUCTION, NERVE JOINING, BIOCHEMICAL OR DRUG TREATMENT, CLONAL ANTIBODY, TO ELIMINATE THE NEED FOR PROTHESIS TO REPLACE LIMBS AND DIGITS.	IMPROVE PATIENT'S QUALITY OF LIFE.	



Economic recovery in the photographic industry lagged behind the moderate nationwide recovery in 1983. A decline in demand for the industry's products along with reduced exports resulting from the strong U.S. dollar abroad caused the value of manufacturers' inventories to fall to their lowest point since 1979 and also reduced sales volumes and lowered product prices. As shown in Table 11-11, total industry employment fell 7%, in 1983; U.S. exports of photographic equipment and supplies fell 4% to $2.3 billion after a 2% drop in 1982. While shipments increased 77% from 1972 to 1983, a drop in yearly growth of shipments was evident, from a 6.4% increase spanning 1981 to 1982 to a 0.5% increase from 1982 to 1983.

Despite the lower exports and higher unemployment figures for 1983, other factors indicate that the industry is only experiencing a momentary lag behind the national economy and should begin to improve in 1984. For example, the Gross National Photo Product, a key indicator of market health, reached a record high of $15.9 billion in 1982 and is expected to have reached $16.8 billion in 1983, an increase of 8%; consumer spending totaled $8.2 billion in 1982 and is expected to have increased by about 5% to $8.6 billion in 1983. Americans took more pictures than anyone else in the world in 1983--11.75 billion exposures, an increase of one billion over 1982.

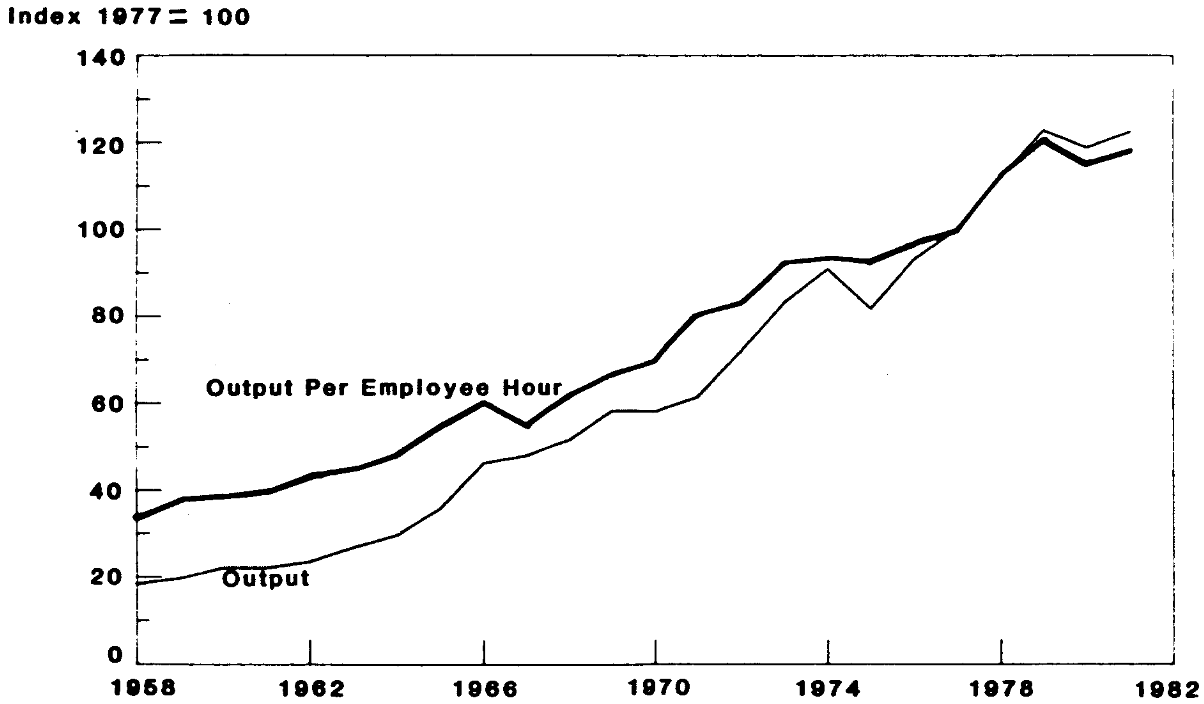
As shown in Table 11-12, the structural profile of the photographic equipment industry, the industry is dominated by four firms that account for 72% of the shipments. The 780 establishments are owned by 702 companies with 515 establishments (66%), employing less than 20 persons.

Constraints affecting the photographic equipment and supplies subdivision are summarized in Table 11-13.

TABLE 11-11

BUSINESS PROFILE OF THE PHOTOGRAPHIC EQUIPMENT AND SUPPLIES INDUSTRY (SIC 386)

SHIPMENTS (BILLION $)	1972	1977	1979	1981	1982	1983
CURRENT DOLLAR	5.6	9.9	13.4	16.9	18.0	18.1
1972 DOLLAR	5.6	7.7	9.5	9.3	9.9	9.9
TOTAL EMPLOYMENT (THOUSANDS)	96.0	111.7	114.1	114.2	116.7	108.7



Source: Unpublished BLS Data

AGE OF PLANT, LEADING FIRMS, 1983 — 7 YEARS

NEW CAPITAL EXPENDITURES, 1983, MILLION $ — 322.7

SOURCES: U.S. DOC/BIE: 1984 U.S. INDUSTRIAL OUTLOOK
U.S. DOC/BOC: CENSUS OF MANUFACTURES, 1977
VALUE-LINE INVESTMENT SURVEYS, 1984
U.S. DOL/BLS

TABLE 11-12

STRUCTURAL PROFILE OF THE PHOTOGRAPHIC EQUIPMENT AND SUPPLIES INDUSTRY (SIC 386)

ESTABLISHMENTS (1977) (CATEGORIZED BY NO. OF EMPLOYEE)		LEADING FIRMS (1983) NAME	DOMESTICALLY GENERATED SALES (MILLION $)
SMALL (<20)	515		
INTERMEDIATE (20-1000)	250	EASTMAN KODAK COMPANY	5065
LARGE (>1000)	15	XEROX CORPORATION	3795
		POLAROID CORPORATION	728
TOTAL (702 COMPANIES)	780	FOTOMAT CORPORATION	260

	MFG. LABOR	OTHER LABOR	MATERIALS	ENERGY	CAPITAL
PRODUCTION COST DISTRIBUTION, 1977	9%	10%	32%	1%	48%

SHIPMENTS ACCOUNTED FOR BY FOUR LARGEST COMPANIES 72%

SOURCES: U.S. DOC/BOC: CENSUS OF MANUFACTURES, 1977
VALUE-LINE INVESTMENT SURVEYS, 1984

TABLE 11-13

DOMINANT CONSTRAINTS AFFECTING THE PHOTOGRAPHIC EQUIPMENT AND SUPPLIES INDUSTRY (SIC 386)

CONSTRAINT	PRINCIPAL IMPACT
FISCAL/MONETARY POLICY	STRONG U.S. DOLLAR LIMITS EXPORTS, HIGH INTEREST RATES LIMIT DOMESTIC INDUSTRIAL AND PROFESSIONAL SALES, WHILE CONSUMER SECTOR IS VULNERABLE TO LEVEL OF CONSUMERS' DISCRETIONARY INCOME.
CYCLICAL MARKET	MARKET CLOSELY TIED TO BUSINESS CYCLE AND PRODUCT INNOVATION CYCLE. END OF RECESSION AND INCREASED CONSUMER CONFIDENCE HELPS SALES.
INVESTMENT RISK	OVER 90% OF U.S. HOUSEHOLDS CURRENTLY OWN CAMERAS. GROWTH OF HARDWARE SALES IS MINIMAL COMPARED TO GROWTH IN THE FILM AND PHOTOFINISHING MARKETS, WHICH HAVE LOWER ROI.
LACK OF VERTICAL INTEGRATION IN CORPORATE STURTURE	HARDWARE IS TYPICALLY PURCHASED FROM HARDWARE MANUFACTURERS, FILM FROM MAJOR FILM MANUFACTURERS: LEADS TO BACKLOGS AND DIFFICULTY PROTECTING PATENTS.

Competitive Issues Affecting the Photographic Equipment and Supplies Industry

In the past few years, the industry has been developing a dichotomous market nature. Products are being developed for a silver imaging market and for a newer high-tech electronic imaging market, as opposed to a single "photo" market. Each of these markets produces products for both amateur/consumer use and industrial use.

Silver Imaging

The silver imaging market retains the traditional flavor of the photographic industry, developing and producing devices that use silver halide in an emulsion method for producing high quality images. These include the traditional products:

- 35mm cameras--both single lens reflex (SLR) and lens/shutter (nonSLR),
- cartridge cameras,
- disc cameras,
- instant photography,
- photographic film, and
- other camera accessories.

35mm Camera Market--Imports provide virtually the sole source of both single lens reflex (SLR) and lens/shutter (nonSLR) 35mm cameras. These cameras account for approximately one-fourth of the total U.S. still camera sales. Any meaningful analysis of this market must start with the realization that there is no longer a single 35mm market, but two markets: the 35mm SLR market and the 35mm lens/shutter market.

The first market, the SLR market, is a relatively high priced, sophisticated one, catering to professionals, serious amateurs and semi-involved amateurs. In the past several years, market growth has come from this last group of consumers, who are mainly affluent buyers with substantial amounts of disposable income.

This market has matured only slightly in recent years. Shipments of SLRs for 1983 were approximately 2.7 million cameras, up only slightly from the 2.6 million units shipped in 1982. This trends suggests that most of the potential SLR users have already been converted to actual users.

The lens/shutter (nonSLR) camera market shows the exact opposite trend. Shipments in 1983 soared to 1.4 million units, up 40% from 1982 and almost 150% over the half million lens/shutter cameras shipped in 1980. These sophisticated cameras have the point and shoot convenience of a box camera, with auto-wind, built-in flash, coated high-speed lens and automatic exposure control features. More importantly, the addition of sophisticated electronics was accompanied by the ability to produce these cameras at incredibly low prices. Selling prices of approximately $100 have created a mass market of amateur users who want the sophistication of SLR cameras without the high price. The lens/shutter camera will become increasingly popular in coming years.

Cartridge Cameras--Sales of 110 cartridge-loading cameras fell sharply in 1983, partially as a result of increased competition from disc cameras and 35mm lens/shutter cameras which offer considerable advantages for only slightly more money. Approximately 3.5 million cartridge-loading cameras were sold in 1983, down 12% from 1982 and 50% from 1981. The accelerated decline of this market may also be attributable to the fact that these cameras are sold in a market where better than 90% of the households have cameras. Many of the consumers in this market are blue collar workers who have been severely affected by the recession. Although the recession is officially over, its impact will linger for a while, especially in the area of luxury items. This lingering effect, together with the increasing popularity of the disc and lens/shutter models, will contribute to the decline and probable elimination of this market.

Disc Cameras--In 1982, disc camera shipments exceeded those of cartridge cameras despite the generally reduced demand for photographic equipment. Eastman Kodak, which developed the disc camera, supplied virtually all of the five million disc cameras shipped to U.S. retailers and the three million units to foreign customers, in 1982. However, in 1983, less than two years after its introduction, the disc camera was being produced in low cost versions by camera makers in Hong Kong, Taiwan, Japan and Germany. Domestic and foreign manufacturers together shipped between five and six million units to U.S. retailers.

Instant Photography--Consumer purchases of instant cameras are shrinking. Sales of instant cameras remained at approximately 3.5 million units for 1983, the same as in 1982, and down 1.5 million units from 1981. Japanese instant cameras and film, which reached foreign markets two years ago, have adversely affected U.S. foreign sales. Attempts to reverse this downward trend include the introduction of instant films with faster speeds and films that allow the separation of the print from the development backing. Other innovations include infrared light sensing and electronic prejudging of the amount of light needed. The identification of new markets in the technical and industrial areas should offer future growth for those instant cameras that have been previously introduced into the market. Since technology in this field has not advanced too rapidly, the existing units will certainly support the instant film industry.

Photographic Film--The value of sensitized photographic film and plate shipments was approximately $4.7 billion during 1983. Recent technological improvements include advances in image sharpness, grain and speed. For example, disc camera film uses a precisely calculated formula of color couplers to increase the development of silver halide crystals in lightly exposed areas, improving color contrast and sharpness.

U.S. manufacturers also introduced ISO 1000 film in 35mm format. This film, the world's fastest, allows for exposures under very low lighting conditions. The push to develop faster, more light sensitive films can be expected to continue for the next several years. The new transparency film technologies make possible the processing of slides and instant prints from slides in less than five minutes without darkroom facilities.

The Japanese have introduced their own disc films and improvements to existing color film lines. To attract attention to these products, Japanese suppliers have increased their advertising and promotional campaigns, including the sponsoring of major events such as the 1984 Los Angeles Summer Olympics.

Retail sales of photographic film have a direct bearing on photofinishing services. The increased number and variety of photographic films have helped to encourage an increase in the number of exposures, especially by amateur consumers. In 1983, exposures increased 6% to 11.4 billion, with 95% of consumers using color film. The new films should also increase the number of good exposures per roll which in turn encourages reprints and enlargements. Thus, increased film quality will continue to encourage growth in photofinishing services.

Other Camera Accessories--Two other major categories, electronic flash units and interchangeable lenses, also declined in 1983.

Electronic flash dropped from 3.0 million units shipped in 1982 to 2.5 million units in 1983. A prime reason for this decline is the incorporation of built-in flash units in most of the current lens/shutter (nonSLR) cameras, which should lead to more convenience and value and stimulate sales of the 35mm lens/shutter cameras.

While interchangeable lens shipments increased by 10% from 3.0 million units to 3.3 million for 1983, this was still below the record 3.4 million lenses shipped in 1981. Approximately, 60% of lenses sold are zoom lenses. Although significantly more expensive, one zoom lens can function in place of three or four fixed focal length lenses. Increased usage of zoom lenses will continue to affect the shipments of interchangeable lenses.

Electronic Imaging

The electronic imaging, or video, market has been entering a transition phase, from a small enthusiasts' market to a huge mass market. Hardware and software are becoming less expensive and easier to use. Thus, virtually every major photographic company is active in the electronic market as a producer of video cameras, as a marketer of video tapes or as the manufacturer of specialized products combining both silver-imaging and electronic imaging technologies.

Areas covered by electronic imaging include:

- video cassette recorders and tapes,
- video cameras and camcorders,
- microfiche, and
- photocopying.

Video Cassette Recorders and Tapes--As in the case of most video products, sales of video cassette recorders (VCR) and tapes reached record highs in 1983. Total VCR sales of 4 million units for 1983 doubled the 2 million units sold in 1982. Prerecorded tape sales increased from 6 million to 8 million units. Blank tapes experienced a dramatic increase in sales, from 28 million units in 1982 to approximately 50 million units in 1983.

All of these sales trends indicate that the video market will continue a rapid growth period. Another interesting aspect of the development of this market is the change in the average household income of the VCR consumer from $53,000 to $34,000, which indicates that the video market is moving into a truly "middle class" market with mass market growth potential.

Video Cameras and Camcorders--One of the more significant developments in the electronics imaging market was the introduction of an 8mm video camera-recorder system by Eastman Kodak. Introduced in January 1984 together with a complete set of video tapes, this product represents the full-scale entry of a major U.S. photographic company into the electronic imaging market.

Two compact "camcorder" models have been introduced together with a special cradle which provides recharging capability and playing facilities for the video tape. The more expensive "camcorder" model offers many of the conviences of the Super 8 movie cameras, including automatic focus and power zoom. The less expensive model has manual focus and fewer automatic features. This product is clearly aimed at Kodak's traditional "family" market, with its integrated design and easy-to-use features. However, the wide range of video tape formats being offered with the system also allow wide-range professional applications.

Tables 11-14 and 11-15 show the top ten foreign consumers of U.S. photographic goods and the top ten foreign suppliers of photographic goods to the domestic market, respectively. U.S. exports are spread relatively evenly among the top five consumers, but imports are not evenly distributed. Japan accounts for 71% of 1982 U.S. imports of photographic goods. Most imports are also showing very rapid growth rates, especially in comparison with the low growth rates of U.S. exports. Figure 11-6 reflect the recent foreign market activity. From this Table it is evident that the U.S. positive balance of trade has been declining at a rate of about 9.5% per year from 1972 through 1983.

TABLE 11-14

COMPARISON OF EXPORTS TO LEADING FOREIGN COUNTRIES (TOP 10)

COUNTRY	**VALUE OF EXPORTS (MILLION $)** 1982	1979	**EXPORT GROWTH RATE 1979-82 (%)**	**PERCENT SHARE OF TOTAL 1982 EXPORTS**
CANADA	317.0	256.9	23.4	12.6
JAPAN	270.3	233.6	15.7	10.8
U.K	263.9	233.5	13.0	10.5
NETHERLANDS	196.1	150.2	30.6	7.8
FRANCE	172.8	120.0	44.0	6.9
F.R. GERMANY	167.7	223.1	-24.8	6.7
AUSTRALIA	106.8	97.2	9.9	4.3
UNITED ARAB EMIRATES	102.1	42.8	135.5	4.1
ITALY	82.7	77.1	7.3	3.3
MEXICO	76.2	80.1	-4.9	3.0
TOTAL	**2248.5**	**1514.5**		**70.0**

1982 TOTAL EXPORTS (ALL COUNTRIES): $2.5 BILLION

SOURCE: MODERN PHOTOGRAPHY MAGAZINE: 1983-84 WOLFMAN REPORT ON THE PHOTOGRAPHIC INDUSTRY IN THE UNITED STATES

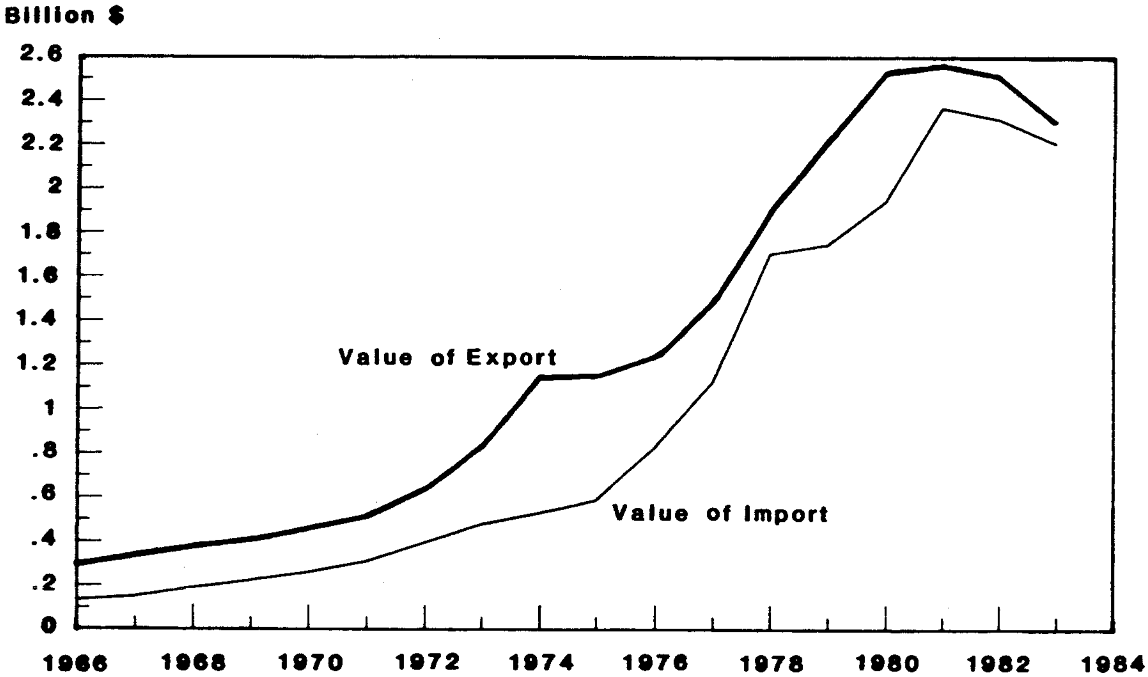
TABLE 11-15

COMPARISON OF IMPORTS FROM LEADING FOREIGN COUNTRIES (TOP 10)

COUNTRY	VALUE OF EXPORTS (MILLION $) 1982	1978	EXPORT GROWTH RATE 1979-82 (%)	PERCENT SHARE OF TOTAL 1982 EXPORTS
JAPAN	1642.4	1190.8	37.9	71.0
BELGIUM	136.5	61.7	121.1	5.9
CANADA	103.4	56.9	81.7	4.5
F.R. GERMANY	99.1	138.5	-28.4	4.3
TAIWAN	87.1	51.2	70.1	3.8
U.K.	58.0	39.3	47.6	2.5
HONG KONG	44.6	43.7	2.0	1.9
FRANCE	31.6	9.6	229.2	1.4
KOREAN REPUBLIC	24.2	18.8	28.7	1.0
ITALY	21.6	19.4	11.3	1.0
TOTAL	2248.6	1629.9		97.3

1982 TOTAL IMPORTS (ALL COUNTRIES): $2.3 BILLION

SOURCE: MODERN PHOTOGRAPHY MAGAZINE: 1983-84 WOLFMAN REPORT ON THE PHOTOGRAPHIC INDUSTRY IN THE UNITED STATES



Source: Department of Commerce and National Association of Photographic Manufacturers-1984 Wolfman Report on the U.S. Photographic Industry

Figure 11-6. Competitive Posture of the Photographic Equipment and Supplies Industry

Productivity in the Photographic Equipment and Supplies Industry

The figure in Table 11-11 shows that the U.S. productivity (output per employee hour) has been steadily increasing in this industry since 1967 at a rate of about 6% per year, with the exception of a slight downturn because of poor market conditions in 1980. At the same time, the Japanese productivity growth rate has been about four times higher. One cause of these high increases in productivity is the incorporation of inexpensive electronics in 35mm cameras, which eases manufacturing labor costs while bringing the product cost down.

Capital costs account for the largest proportion of production costs (48%). R&D amounts to around 15% of the value of industry shipments. Materials costs amount to 32% and are largely due to the precise requirements for product components, especially lenses and precision mechanisms. Labor costs amount to 19% of production costs and, therefore, do not have as large an effect on the product price as materials and capital costs.

Role of Technology in the Long-Term Strategic Outlook

Growth in the photographic equipment and supplies industry is highly cyclical. There is a surge in demand for new products immediately after an innovation is introduced to the market; but, in time, market demand for the product drops as a result of market saturation. The industry is therefore, classified as neither sunrise or sunset, but as cyclical.

The photographic equipment and supplies industry is a general indicator of socioeconomic conditions that reflect changes in unemployment, economic stability, family size, and consumer confidence. Cameras are generally considered a luxury item; thus, for the average consumer, camera and film sales reflect the amount of disposable income available.

As was previously mentioned, industry market performance is based in part on product innovation. The lens/shutter 35mm camera is a big seller and should continue to be in the near future, as technology improvements enable manufacturers to produce more highly automatic and cheaper products. New faster-speed films should result in more demand for film processing labs. The electronic imaging market should also grow, although silver halide imaging will still be the dominant method for the next generation of cameras; electronic imaging promises to be important to the long-term growth of this industry. Double digit growth of the video market will continue. Electronic enhancement will contribute to the growth of imaging labs and film scales providing sharper and clearer highlights on prints. The new 35mm camera will be a simplified SLR with some sort of telephoto or wide angle capability incorporated in it along with digital electronics that incorporate DX reading systems. DX is a black and silver digital code printed on the film that indicates the film type and speed for which the camera should set itself and establishes an automatic developing system (DX code developed in March of 1983 by KODAK Corp.). New product technologies and probable dates of significant dispersion throughout the industry are provided in Table 11-16.

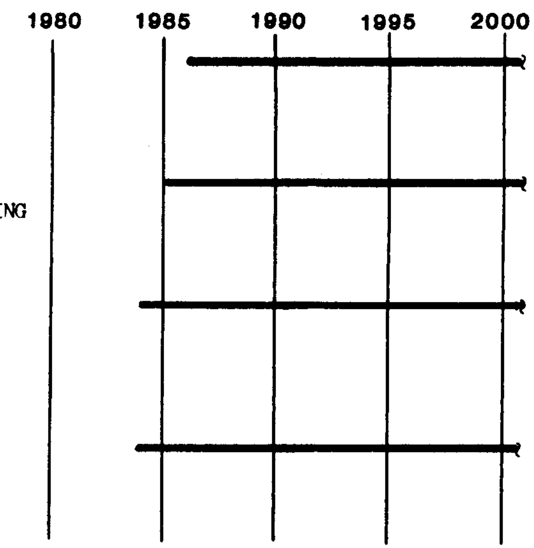
Summary

The photographic equipment and supplies manufacturing industry subdivision is characterized by a wide variety of products; including consumer market products such as hand-held cartridge and instant cameras, and business and industrial products such as film-processing equipment, photocopiers, microfilming equipment, cameras, and accesories for professional or industrial applications. U.S. producers will face increasing competitive pressure from Japan as it makes further advances in the U.S. domestic market. Given the nature of market risks and the cyclical nature of the photographic equipment and supplies market, it is especially difficult to predict what new technologies will appear on

TABLE 11-16

NEW PHOTOGRPAHIC TECHNOLOGIES

TECHNOLOGY	DESCRIPTION	PRINCIPAL IMPACT	APPROXIMATE ERA OF SIGNIFICANT DIFFUSION
ELECTRONIC STILL CAMERA	ELECTRONIC VIEWER WHERE PICTURES ARE DIGITALLY STORED ON MAGENTIC DISK.	EASIER TO USE CAMERA, PICTURE QUALITY DOES NOT DEGRADE.	
ELECTRONIC IMAGING (VCR, VHS, ETC)	VISUAL DATA IS DIGITIZED AND STORED ON DISK OR TAPE.	REDUCED CONSUMER PRICE FOR MOTION PICTURE TAKING AFTER INITIAL OUTLAY.	
COLOR FILM PRINTERS	HARDCOPY COLOR GRAPHICS: PRODUCE PRINTS OF PHOTO-GRAPHIC QUALITY FROM COLOR GRAPHICS TERMINAL OR VIDEO.	CAPABLE OF PRODUCING CONTINUOUS TONE IMAGES, BUT VERY EXPENSIVE.	
INK JET COLOR PRINTERS	HARDCOPY COLOR GRAPHICS: ELECTRONICALLY CONTROLLED JETS OF INK BASED ON DIG-ITAL IMAGE DATA.	QUIET, HIGH-SPEED PRINTING ON PLAIN PAPER.	



the horizons, or what their impact on the photographic equipment and supplies industry will be in the future.

B.11.4 CONCLUSIONS

Of the three subdivisions of the instruments and related products manufacturing subsector selected for in-depth analysis, both optical instruments and lenses, and surgical, medical and dental instruments are classified as sunrise industries, while photographic equipment and supplies is a cyclical industry. One leapfrog technology that may be applicable to the engineering and scientific personnel shortage in optical instrument manufacturing is accelerated learning. Leapfrog technologies affecting the surgical, medical, and dental instruments industry are custom multiproperty materials for biocompatible implants and prosthetics, new medical and biotechnology, and mobile energy storage systems for some prosthetics or artificial organs. New film and imaging technologies should have the greatest impact on the U.S. photographic equipment and supplies industry. Potential leapfrog technologies for this industry include custom multiproperty materials for an advanced image storage medium and novel mobile energy storage devices (such as long-life lithium batteries) to improve the performance of off-the-shelf imaging equipment.

B.12 "STONE, CLAY AND GLASS" (SIC 32)

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SOURCES: U.S. DOC/BOC:

Statistical Abstract of the U.S., 1982-3

Census of Manufactures, 1977

Annual Survey of Manufactures, 1981

U.S. DOC/BIE:

1984 U.S. Industrial Outlook

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B.12 "STONE, CLAY, AND GLASS" (SIC 32)

The stone, clay, and glass subsector, SIC 32, includes establishments engaged in manufacturing flat glass and other glass products, cement, structural clay products, pottery, concrete and gypsum products, ceramics, cut stone, and asbestos products from materials taken from the earth in the form of stone, clay, and sand. The subsector accounted for 3.1% of the manufacturing sector's value added contribution to GDP in 1980, ranking it twelfth within the 20 manufacturing subsectors. This subsector is characterized by:

- A high degree of fragmentation. Out of a total of approximately 18,000 establishments, 13,000 employed less than 20 persons (1977).

- A labor productivity of $21,979 per employee or $11.45 per employee hour (1980, 1972 $), ranking this subsector tenth among the nation's 20 manufacturing subsectors. A compound annual labor productivity growth rate average of 1.1%/year from, 1972 to 1980 ranks this subsector twelfth. The labor productivity for the comparable Japanese subsector was $12,897 per employee year or $6.72 per employee hour (1980, 1972 $), ranking this subsector eighth among Japan's 20 manufacturing subsectors. The compound annual labor productivity growth rate for the Japanese subsector averaged 5.8%/year from 1972 to 1980, ranking it third.

- A slightly higher than average capital investment base relative to other subsectors within the manufacturing sector. Capital investment amounted to $23,796 in total assets per worker, ranking fifth in terms of (depreciated) fixed assets (1980, 1972 $). New yearly capital expenditures were $2,784 per employee (1980, 1972 $), ranking sixth in the manufacturing sector.

Total capital productivity, measured as dollars of added value output per dollar of capital investment, was 0.47 (1981).

- A less than average R&D program. For the subsector as a whole, R&D expenditures amounted to $0.2 billion (1980, 1972 $), equivalent to 1.7% of the value added by the subsector in 1980, ranking this subsector twelfth among the 20 manufacturing subsectors.

Table 12-1 shows the major products of each subdivision of the stone, clay, and glass subsector, ranked in descending order in terms of their share of the subsector's contribution to GDP in 1980. Table 12-2 summarizes the principal economic measures of these subdivisions.

One subdivision--Concrete, Gypsum, and Plaster Products (SIC 327)--accounted for 30% of the subsector's output in 1980. Three other subdivisions--Glass Pressed or Blown (SIC 322), Pottery and Related Products (SIC 326), and Miscellaneous Nonmetallic Mineral Products (SIC 329)--all produce advanced ceramic products which are significant because of the technologies that their production requires. In assessing long-term technology needs, we have selected Concrete, Gypsum, and Plaster Products (SIC 327), and also the advanced ceramic products industry for further analysis.

B.12.1 CONCRETE, GYPSUM, AND PLASTER PRODUCTS (SIC 327)

Concrete Block and Brick (SIC 3271), Concrete Products (SIC 3272), and Ready-Mixed Concretes (SIC 3273) contributed 88% to the value of shipments of the concrete, gypsum and plaster products subdivision (SIC 327). Therefore, these three industries will be considered together in this analysis.

The concrete products industries include establishments that manufacture concrete building block and brick, concrete products,

TABLE 12-1

CLASSIFICATION OF THE MAJOR PRODUCTS OF THE STONE, CLAY, AND GLASS SUBSECTOR (SIC 32), AND RELATIVE CONTRIBUTION TO GDP IN 1980

SIC CODE	SUBDIVISION DESIGNATION AND TYPICAL PRODUCTS	% CONTRIBUTION
327	**CONCRETE, GYPSUM, AND PLASTER PRODUCTS**	29.9
	CONCRETE BLOCKS, AND BRICKS, DRY MIX CONCRETE, GRAVE MARKERS, SILOS, LIME, PLASTER OF PARIS, AND GYPSUM BOARD.	
329	**MISCELLANEOUS NONMETALLIC MINERAL PRODUCTS**	23.0
	ABRASIVE BUFFS, BUFFING AND POLISHING WHEELS, HONES, STEEL WOOL, TRIPOLI, ASBESTOS, GASKETS, BARIUM, FLINT, LEAD, SHALE, TALC, GLASS WOOL, AND STUCCO.	
322	**GLASS PRESSED OR BLOWN**	18.2
	JARS, JUGS, MILK BOTTLES, ASHTRAYS, CHRISTMAS TREE ORNAMENTS, OPTICAL GLASS, STEMWARE, AND GOBLETS.	
324	**CEMENT, HYDRAULIC**	8.8
	PORTLAND, NATURAL, MASONRY, AND POZZOLAN CEMENTS.	
323	**PRODUCTS OF PURCHASED GLASS**	5.2
	AQUARIUMS, DOORS, FURNITURE TOPS, AND LABORATORY GLASSWARE.	
325	**STRUCTURAL CLAY PRODUCTS**	5.2
	CLAY TILE OF ALL TYPES, CLAY BLOCK, AND CLAY BRICK.	
326	**POTTERY AND RELATED PRODUCTS**	5.0
	FLUSH TANKS, URINALS, SINKS, DISHES, BONE CHINA, COOKWARE, PORCELAIN KNOBS, SPARK PLUG PORCELAIN, FLOWER POTS, AND PORCELAIN TUBES.	
321	**FLAT GLASS**	3.5
	CATHEDRAL GLASS, PICTURE GLASS, PLATE GLASS, SPECTACLE GLASS, SHEETGLASS, AND WINDOW GLASS.	
328	**CUT STONE AND STONE PRODUCTS**	1.4
	ALTARS, BAPTISMAL FONTS, CURBING SLATE ROOFING, MONUMENTS, URNS, MARBLE STATUARY, AND MARBLE TABLE TOPS.	
	ALL STONE, CLAY AND GLASS PRODUCTS	100.0

SOURCES: U.S. DOC/BOC: STATISTICAL ABSTRACT OF THE U.S., 1982-3
EOP/OMB: STANDARD INDUSTRIAL CLASSIFICATION MANUAL, 1972

TABLE 12-2

SUBDIVISIONS AND CHARACTERIZATION OF THE STONE, CLAY & GLASS SUBSECTOR (SIC 32) DURING 1980, IN 1972 DOLLARS

SUBDIVISION	PERCENTAGE CONTRIBUTION	NUMBER OF EMPLOYEES (1,000)	NUMBER OF ESTABLISHMENTS[a]			GROSS VALUE OF FIXED ASSETS ($/EMPLOYEE)	NEW CAPITAL EXPENDITURES ($/EMPLOYEE)	LABOR PRODUCTIVITY ($/EMPLOYEE)
			TOTAL	LESS THAN 20 EMPLOYEES	100 OR MORE EMPLOYEES			
ALL STONE, CLAY & GLASS PRODUCTS (32)	100	613.3	17,744	12,543	1,236	23,796	2,784	21,979
FLAT GLASS (321)	5	17.3	62	30	24	54,573	8,786	27,288
GLASS PRESSED OR BLOWN (322)	19	110.2	508	259	198	22,936	2,349	22,269
PRODUCTS OF PURCHASED GLASS(323)	5	42.1	1,101	776	91	10,917	1,435	16,684
CEMENT, HYDRAULIC (324)	9	30.4	201	41	132	85,771	7,563	39,075
STRUCTURAL CLAY PRODUCTS (325)	6	43.5	711	240	128	19,239	1,702	15,999
POTTERY AND RELATED PRODUCTS (326)	4	43.4	934	693	105	8,818	877	15,624
CONCRETE, GYPSUM, & PLASTER PRODUCTS (327)	28	189.2	10,844	8,133	251	22,072	2,894	21,316
CUT STONE AND STONE PRODUCTS (328)	1	13.0	993	829	15	7,174	496	12,486
MISC. NONMETALLIC MINERAL PRODUCTS (329)	23	124.2	2,390	1,542	292	20,665	2,738	24,913

[a] 1977

SOURCE: U.S. DOC/BOC: CENSUS OF MANUFACTURES, 1977
ANNUAL SURVEY OF MANUFACTURES, 1981

and portland cement concrete in a ready-mix state. The historical and current posture of these industries is summarized in Tables 12-3 and 12-4, which portray their business and structural profiles, respectively. Table 12-3 shows that, expressed in constant 1972 dollars, shipments of these industries have decreased 12% in eleven years, from $6.9 billion in 1972 to $6.1 billion in 1983. Because of the recent economic recovery, the value of shipments is expected to rise to $6.5 billion in 1984, an increase of 7%. Employment declined by 17%, from a cyclical high of 185 million in 1979, to a low of 154 million in 1983. Labor productivity, i.e., output per employee hour, rose steadily until 1977; general decline has been apparent, however, from 1977 to 1984.

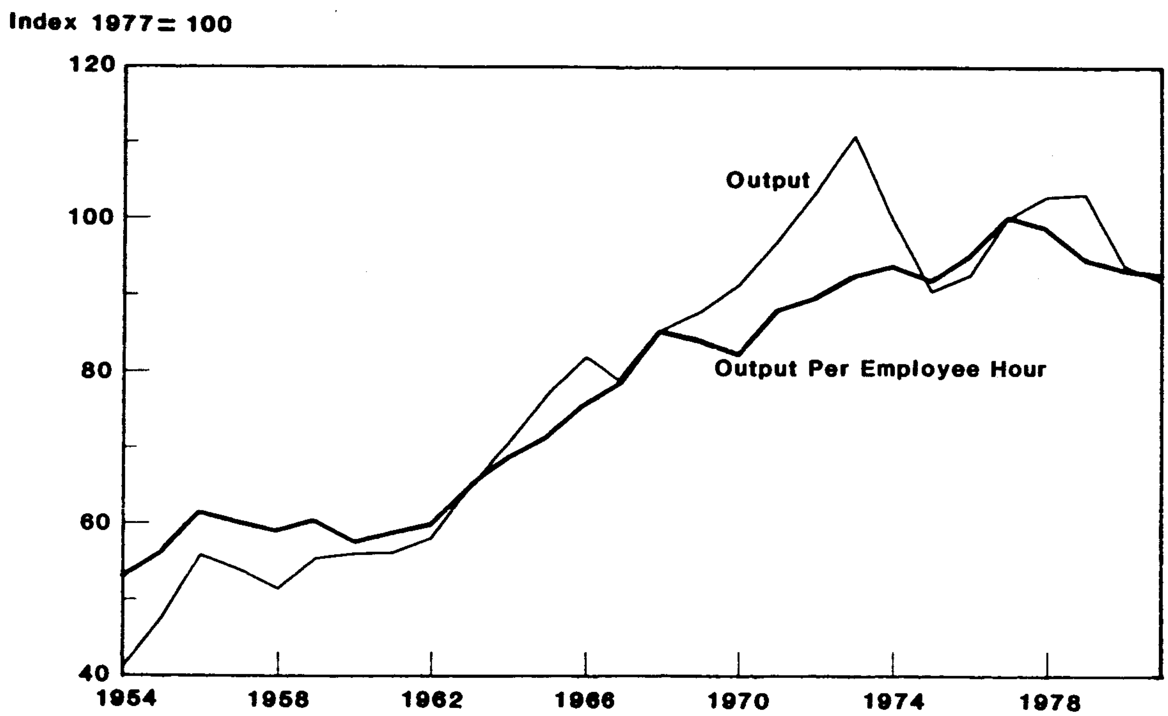
Table 12-4 shows that the concrete products industries' top seven firms accounted for $1.2 billion in sales during 1983. Of the 10,622 establishments, 76% employ less than 20 persons.

Table 12-5 shows that five dominant factors influence or constrain the concrete products industries. These industries are highly fragmented: Approximately 84% of the establishments are single owner firms with an average plant size of 16 persons. Therefore, very few internal R&D programs exist since their economic feasibility is limited by low capital expenditure capabilities and low economies-of-scale. Moreover, the diffusion of external technological innovations from the equipment manufacturing subsectors is slow because of the ownership diffusion among these industries. The industries' market demand closely follows that of the construction sector, and is, therefore, affected by several financial factors: Interest rates tend to fluctuate between wide extremes; companies often have to reserve capital for periods of low market demand because of the cyclical nature of the market, which limits the availability of investment capital for new technological advances.

TABLE 12-3

BUSINESS PROFILE OF THE CONCRETE PRODUCT INDUSTRIES
(SICs 3271, 3272, AND 3273)

SHIPMENTS (BILLION $)	1972	1977	1979	1981	1983	1984 EST.
CURRENT $	6.9	10.3	14.1	14.2	14.5	14.0
1972 $	6.9	6.8	7.3	5.8	6.1	6.5
EMPLOYMENT (THOUSANDS)	176	168	185	165	154	--
CAPITAL EXPENDITURES MILLION 1972$	390	388	490	341	--	--



Source: Published BLS Data

NET PROFIT MARGIN, 1983 % 8.7

SOURCES: U.S. DOC/BIE: 1984 U.S. INDUSTRIAL OUTLOOK
U.S. DOC/BOC: CENSUS OF MANUFACTURES, 1977

TABLE 12-4

STRUCTURAL PROFILE OF THE CONCRETE PRODUCTS INDUSTRIES (SICs 3271, 3272, 3273)

NUMBER OF ESTABLISHMENTS (CATEGORIZED BY NO. OF EMPLOYEES)

SMALL (<20)	8,057
LARGE (>20)	2,567
TOTAL (8954 COMPANIES)	10,624

LEADING FIRMS (1983)

NAME	SALES (MILLION 1972$)	NO. OF EMPLOYEES
LONE STAR INDUSTRIES	435	8700
GIFFORD-HILL	186	3600
IDEAL BASIC	178	3415
TEXAS INDUSTRIES	152	3100
SOUTHDOWN	114	1100
KAISER CEMEMT	102	1449

	MFG. LABOR	OTHER LABOR	MATERIALS	ENERGY	CAPITAL
PRODUCTION COST DISTRIBUTION, 1977	13%	7%	52%	2%	26%

R&D EXPENDITURES, (ALL SIC 32) CURRENT MILLION $, 1980	406

TRADE (MILLION 1972 $)	1972	1977	1979	1981	1983
VALUE OF EXPORTS	1.1	9.8	7.0	6.4	7.8
VALUE OF IMPORTS	7.9	4.0	10.2	8.9	8.5

SOURCES: U.S. DOC/BOC: CENSUS OF MANUFACTURES, 1977
1984 VALUE-LINE INVESTMENT SURVEY

TABLE 12-5

CONSTRAINT PROFILE OF THE
CONCRETE PRODUCTS INDUSTRIES

OWNERSHIP STRUCTURE	HIGHLY FRAGMENTED. AT LEAST 84% OF ESTABLISHMENTS ARE ONE PLANT FIRMS
INNOVATION	NEW TECHNOLOGY IS ADOPTED FROM OTHER INDUSTRIES (EQUIPMENT MANUFACTURING)
FISCAL/MONETARY POLICY	INDUSTRY IMPACTED BY INTEREST RATE FLUCTUATIONS
AVAILABILITY OF INVESTMENT CAPITAL	LOW COMPARED TO OTHER INDUSTRIES
MARKET DEMAND PATTERN	HIGHLY CYCLICAL, CLOSELY FOLLOWS THE CONSTRUCTION SECTOR

SOURCES: U.S. DOL/BLS

Competitive Issues Affecting the Concrete Products Industries

Table 12-4 summarizes export and import statistics for the concrete products industries. During the eleven year period from 1972 to 1983, exports rose over 600% from $1.1 million to $7.8 million (1972 $); imports rose by only 8% in the same period, from $7.9 million to $8.5 (1972 $). In 1983 the balance of trade showed only a $0.6 million (1972 $) deficit, while imports and exports were only 0.2% of total shipments, suggesting that foreign trade, most of which is with neighboring countries, is likely to remain small.

Productivity in the Concrete Products Industries

The data in Table 12-3, drawn from published BLS data, show that productivity for concrete products (excluding ready-mixed concrete) increased at an average annual rate of 3.1% from 1960 to 1977, as compared to 2.6% for all manufacturing. This increase in productivity can be partially attributed to the increased use of concrete products in the construction market because of the more widespread application of precast and pre-stressed concrete as opposed to structural steel and timber. Another reason for this rise in productivity was a 21% decline in smaller, less efficient concrete block establishments between 1967 and 1977. The recent drop in productivity--2.1% average annually from 1977 to 1981--derives from the impact of the recent recessions on the construction industry, which has reduced the market for concrete products.

As shown in Table 12-4, materials in the concrete products industry during 1977 totaled 52% of production costs, followed by capital expenditures at 26%, manufacturing labor at 13%, other labor at 7%, and energy costs at 2%.

Role of Technology in the Long-Term Strategic Outlook

The concrete products industries have been penetrating the construction sector (i.e., replacing traditional steel markets) through the use of improved reinforcing techniques in conjunction with other materials. The ability of concrete to be molded in virtually any shape or size enhances its appeal to architects. Energy conservation advantages can also be realized through the use of concrete: Passive solar applications are possible due to their heat absorption properties. The strength and resistance to earth conditions of concrete enhances its use for underground and earth-covered construction. These properties and the new commercial appeal of concrete indicate that the concrete products industry has not yet reached a saturation point with regards to the construction market. From 1984 to 1988, the industries constant dollar shipments are expected to rise 3%, exceeding the expected rate of growth of the construction sector.

New Technologies in the Concrete Products Industries

Table 12-6 summarizes the new technologies currently being developed and used by the concrete products industries. A synopsis of these technologies follows:

- Material handling technology is a major component of concrete products manufacturing. The highly mechanized systems use mobile platforms to move newly cast concrete to different operations inside the plant. Automatic cubers are used by the largest block plants in place of manual methods. The automatic cuber requires only periodic supervision and replaces four unskilled workers. The use of material handling technology can reduce the labor force required by 50%. Diffusion of these systems throughout the industry will be slow due to the number of small plants.

TABLE 12-6

NEW TECHNOLOGIES IN THE CONCRETE PRODUCTS INDUSTRIES (SICs 3271, 3272, 3273)

TECHNOLOGY	DESCRIPTION	PRINCIPAL IMPACT	APPROXIMATE ERA OF SIGNIFICANT DIFFUSION (1975 / 1980 / 1985 / 1990)
IMPROVED MATERIAL HANDLING EQUIPMENT	PLATFORMS, TRANSFER CARS, OR CONVEYORS MOVE CONCRETE AND STACK IT AUTOMATICALLY. USED IN 25% OF PLANTS (1979), EXPECTED TO INCREASE IN LARGER PLANTS	REDUCES NEED FOR UNSKILLED LABOR	
IMPROVED CASTING METHODS	MORE EFFICIENT BLOCK MACHINES, SPECIALTY PRECASTING MACHINES, IMPROVED PRESTRESSED CONCRETE MANUFACTURING. USE LIMITED TO LARGER PLANTS (1979)	REDUCES LABOR REQUIREMENTS, MAKES STRONGER CONCRETE	
CURING METHODS: HOT CONCRETE, HOT OIL, AND AUTOCLAVE	PREHEATS CONCRETE FOR FASTER STRIPPING, REDUCES CURING TIME. HOT OIL USE WIDESPREAD, AUTOCLAVING IN 25% OF PLANTS, HOT CONCRETE USE LIMITED (1979)	SAVES UNIT LABOR COSTS	
AUTOMATIC BATCHERS	QUALITY OF CONCRETE IMPROVED THROUGH ELECTRONICALLY SELECTED, WEIGHED, AND PROPORTIONED AGGREGATES. USE IN 10% OF PLANTS, DIFFUSION TO SMALLER PLANTS UNLIKELY (1979)	OPERATOR NO LONGER CONTROLS PROCESS, ONLY MONITORS	

SOURCE: U.S. DOL/BLS

- Improved casting methods for blocks, specially designed precast shapes, concrete panels, and standard prestressed products (such as hollow-cored slabs) are being developed. Productivity will increase with the introduction of larger capacity block casting machines. The new machines can produce 1200 to 1600 standard 8-inch units/hour, while older machines developed in the 1960s can produce only 1000 units/hour. The larger block casting machines are currently used by only large block casting firms. Prestressed concrete (in which steel strands, tensioned by hydraulic jacks, are embedded in the concrete to increase tensile strength) is being improved to accelerate the casting process with hydraulic drives in some extruding machines. Diffusion has been very slow because of the small economies-of-scale and high equipment costs.

- Curing technologies will reduce labor in the concrete products industries by reducing inventories. Most firms currently cure concrete in the storage yard (because of the seasonal nature of the industry) which causes high inventory. Hot oil curing pumps hot oil under the length of the casting bed to heat and harden the concrete. Autoclave curing (for blocks and other small precast products) uses high pressure steam to cure the concrete and takes half the time of the old curing method. The hot concrete curing method preheats the concrete in the mixer, allowing it to cure in approximately half the time. Once again, diffusion will be slow due to industry fragmentation.

- Automatic batches improve quality control and allow for greater flexibility, although no actual labor savings are realized. These are used most often by manufacturers of ready-mixed concrete. Automatic batches electronically select, weigh, and apportion specific amounts of aggregates and cement for particular concretes. Computer integration of automatic batchers is also being implemented. Slow diffusion due to industry fragmentation is again the limiting factor.

Technological diffusion is generally limited throughout these industries by their small plant sizes, small local markets, and the cyclical demand for concrete. The extension of construction activity and, in particular, concrete manufacturing to a year-round function, and the greater standardization of building equipment, would improve conditions for technological diffusion.

Conclusion

Although the performance of the concrete products industries has historically been tied to that of the construction sector, the concrete products industries constant dollar shipments are expected to outgrow those of the construction sector in the next four years (1984-1988). This is due to the widespread application of precast and prestressed concrete in situations were structural steel and timber were used previously. This indicates that the concrete products industries have room for growth.

In summary:

- The ownership structure of these industries (84% of establishments are one plant firms) has impeded R&D activities due to the lack of capital.

- Foreign trade is not likely to be a factor in the industry due to the bulkiness of the product. Currently, most trade is with neighboring countries.

- There has been a recent drop in productivity (2.1% average annual decrease from 1977 to 1981) due to the depressed nature of the construction industry.

- Any new technologies in the concrete products industries will diffuse slowly due to the ownership structure, and the cyclical and seasonal nature of these industries.

B.12.2 ADVANCED CERAMIC PRODUCTS INDUSTRY

The advanced ceramic (AC) products industry, like many new emerging industries, is not classified within the Standard Industrial Classification System, whose codes have not been revised since 1972. Rather, this industry combines elements from several subdivisions, including Glass Pressed or Blown (SIC 322), Pottery and Related Products (SIC 326), and Miscellaneous Nonmetallic Mineral Products (SIC 329). This industry includes establishments which manufacture AC products valued for their hardness, strength, and their thermal and electrical properties, all of which are used in high-performance engines, machines, and electronic components.

The current and estimated future business profile of the advanced ceramic industry is summarized in Table 12-7. Expressed in constant 1972 dollars, industry shipments are forecasted by DOC to increase nearly ten fold in 20 years, from $335 million in 1980 to $3.26 billion in 2000. This growth can be broken down into industry components. Figure 12-1 illustrates U.S. AC industry shipments (by end use) for 1980 (1972 $); these include integrated circuit packaging (38% of the total), capacitors (39%), resistors (13%), cutting tools (7%), and wear parts (3%).

Integrated circuit packaging, the fitting of semiconductor integrated circuits into larger boards, provides a suitable operating environment within a computer for a working microchip. Materials used in capacitors, by shipments in 1982 (Figure 12-2), shows that ceramic use accounted for 78% of shipments. This segment of the industry is expected to grow 877% in the next 20 years, from $123 million in 1980 to $1.2 billion (1972 $) by the year 2000. Capacitors, which store electric energy control

TABLE 12-7

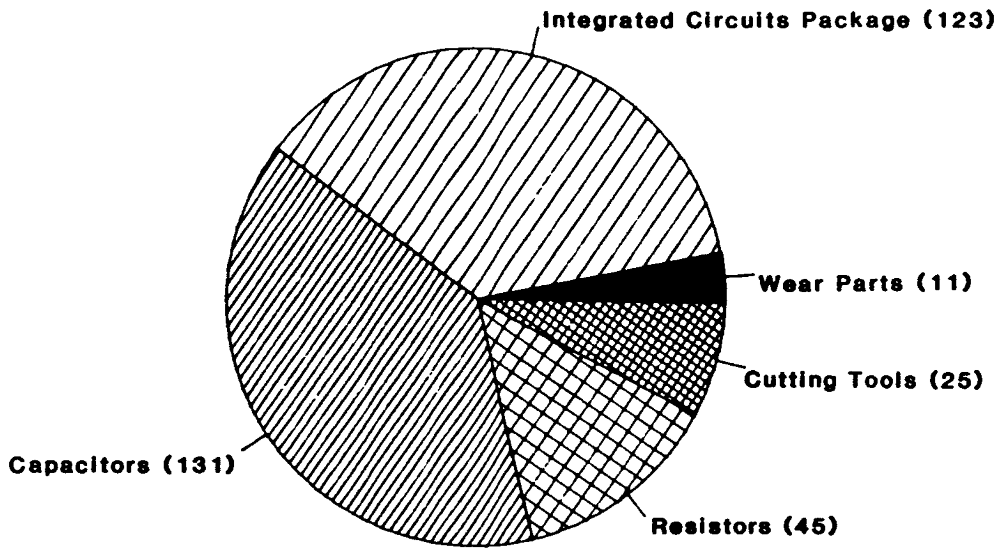
BUSINESS PROFILE OF THE
ADVANCED CERAMICS INDUSTRY

VALUE OF CERAMICS CONTENT IN U.S. INDUSTRY

SHIPMENTS (MILLIONS 1972 $)	1980	1985	1990	1995	2000
ALL INDUSTRY	335	728	1396	2200	3265
ELECTRONIC COMPONENTS	299	610	1051	1466	1953
• INTEGRATED CIRCUIT PACKAGING	123	331	583	886	1202
• CAPACITORS	131	195	336	407	504
• OTHER ELECTRONIC USES	45	84	132	173	247
ENGINEERING PRODUCTS	36	118	345	734	1312
• CUTTING TOOLS	25	81	213	336	538
• WEAR PARTS	11	25	101	210	303
• HEAT ENGINE PARTS	0	12	31	188	471

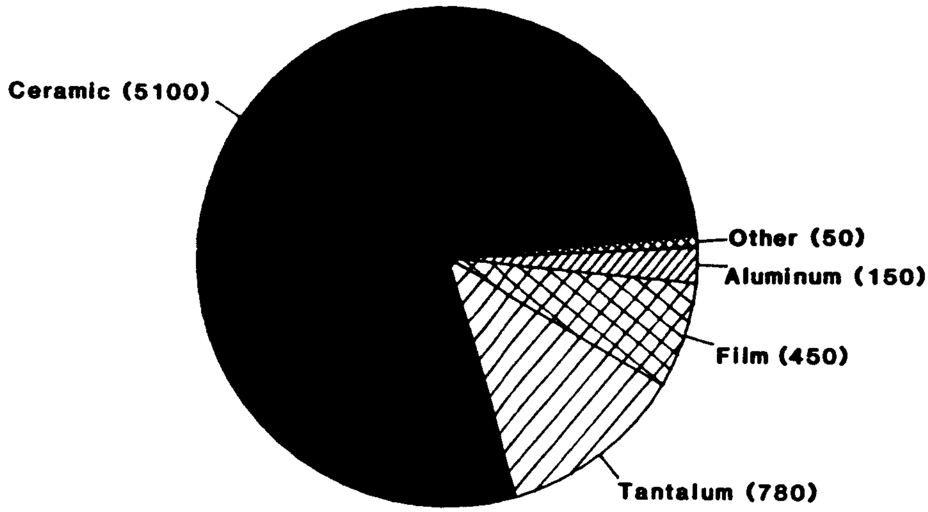
FEDERAL GOVERNMENT FUNDED R&D FOR ENGINEERING CERAMIC TECHNOLOGY, FY 1982	AMOUNT (MILLION 1972 $)
DEPARTMENT OF ENERGY	8.1
• VEHICLE AND ENGINE R&D	5.2
• INDUSTRIAL PROGRAM	0.2
• ENERGY SYSTEMS RESEARCH	0.2
• OTHER	2.5
NASA	0.8
NATIONAL SCIENCE FOUNDATION	0.6
DEPARTMENT OF DEFENSE	3.3
TOTAL	12.8

SOURCES: U.S. DOC/INDUSTRY ANALYSIS DIVISION
U.S. DOE/OFFICE OF VEHICLE & ENGINE R&D



Source: U.S. DOC/Industry Analysis Division,
Office of Chemical and Allied Products.

Figure 12-1. U.S. Advanced Ceramic Shipments by End Use



Source: U.S. DOC/Bureau of Industrial Economics.

Figure 12-2. U.S. Capacitor Shipments by Materials Used for 1982

the flow of alternating current, and block the flow of direct current, are a major segment of the AC industry. A growth rate of 285% in twenty years is expected, from $131 million in 1980 to $504 million (1972 $) in the year 2000. Other electronic uses, such as magnetic components, resistors, and sensors are expected to grow from $45 million in 1980 to $247 million by 2000, a 449% increase.

Advanced ceramics are being used extensively in cutting tools, due to their hardness. The majority of these ceramic cutting tools are used by the aircraft engine industry for machining specialized superalloys and by the automotive industry for cast iron machining. From 1980 to the year 2000, the shipments of AC cutting tools are expected to rise from $25 million to $538 million, (1972 $) a 2052% increase. Their use in wear parts, ball bearings, pump parts, mechanical seals, nozzles, etc., is currently limited, but is expected to rise. In the next 20 years, a 2655% jump in overall use could be realized, from $11 million to $303 million (1972 $). Heat engine parts are not being used commercially at the present time; however, by the year 2000 their use should reach the $471 million (1972 $) mark.

These figures generally suggest that the AC industry will grow rapidly and diffuse into many different industries. Table 12-8 shows major firms in the U.S. currently involved in advanced ceramic production and research, by type of product.

Competitive Issues Affecting the Advanced Ceramics Industry

Figures 12-3 and 12-4 show the percent of international patents issued, from 1970 to 1982, in ceramic compositions and ceramic coatings products, respectively. Figure 12-3 shows that U.S. international patents on ceramic compositions decreased from 78% in 1970 to 50% in 1982; among foreign competitors, Japan's international patents increased from 6% in 1970 to 24% in 1982. Figure 12-4 shows that U.S. international patents on ceramic

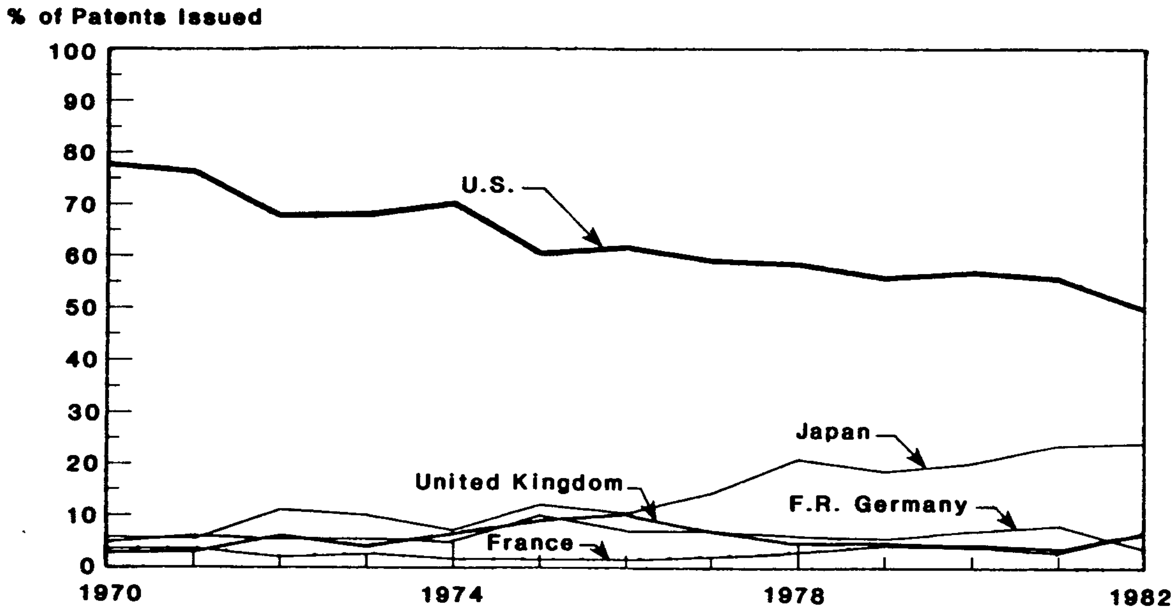
TABLE 12-8

U.S. FIRMS CURRENTLY INVOLVED IN ADVANCED CERAMIC PRODUCTION AND RESEARCH, BY PRODUCT TYPE

CERAMIC POWDER PRODUCERS	INTEGRATED CIRCUIT PACKAGING (IC)	CAPACITORS	OTHER ADVANCED CERAMICS	CERAMIC POWDERS, ICs CAPACITORS AND OTHER ADVANCED CERAMICS COMBINED
CORNING GLASS	MONSANTO	AVX	MONSANTO	IBM
COORS PORCELAIN	BRUSH WELLMAN	KEMET	GTE SYLVANIA	HONEYWELL
NORTON	INTERAMICS	SPRAGUE	PLESSEY, INC.	G.E.
CARBOUNDUM	CERAMIC SYSTEMS	CENTRALAB	CERAMICS INTL.	TEXAS INSTRUMENTS
ALCOA		STE		MOTOROLA
TAM CERAMIC		CORNING GLASS		RCA
AMERICAN LAVA		VITRAMON		
		UNITRODE		

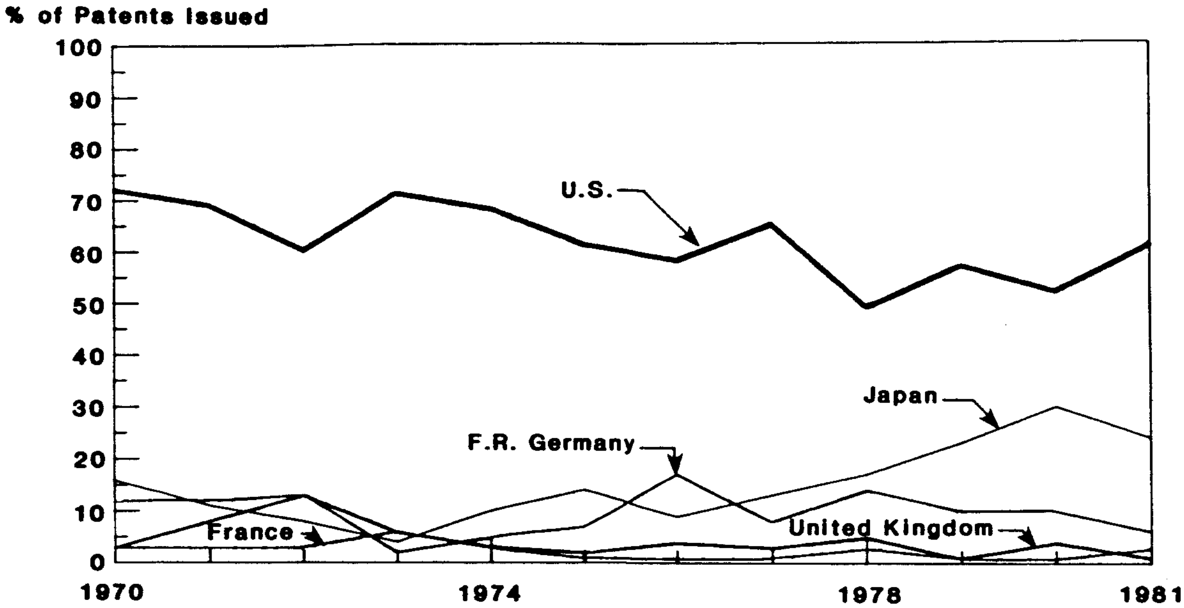
CUTTING TOOLS	WEAR PARTS	ENGINE DESIGN	CERAMIC MATERIALS AND PARTS
KENNAMETAL, INC.	CARBORUNDUM	FORD MOTOR	CARBORUNDUM
BABCOCK AND WILCOX	GENERAL ELECTRIC	CATERPILLAR TRACTOR	DUPONT
COORS PORCELAIN	NORTON	GARRETT	CELANESE
TRW	COORS PORCELAIN	CUMMINS	DOW-CORNING
ADAMS CARBIDE	ART INC.	GENERAL MOTORS	NORTON
CARBOLOGY SYSTEMS DEPT.	ESK	WESTINGHOUSE	CORNING GLASS
GTE WALMET		INTERNT'L HARVESTOR	COORS PORCELAIN
TALIDE METAL CARBIDES		G.E.	CERAMTECH INC.
VALENITE		PRATT AND WHITNEY	GTE SYLVANIA
TELEDINE FIRST STERLING		HAGUE INTERNT'L	G.E.
			KAMAN SCIENCES
			UNITED TECHNOLOGIES
			AIRESEARCH CASTING
			CERADYNE, INC.

SOURCE: U.S. DOC/INDUSTRY ANALYSIS DIVISION



Source: U.S. DOC, Patent Technology Assessment Forecast,
Custom Report by Patent and Trademark Office, 9/13/83.

Figure 12-3. International Patent Activity-Ceramic Compositions



Source: U.S. DOC, Patent Technology Assessment Forecast, Custom Report by Patent and Trademark Office, 9/13/83.

Figure 12-4. International Patent Activity-Ceramic Coating (Glass or Ceramic Based)

coatings fell from 72% in 1970 to 61% in 1981, whereas Japan's rose from 4% in 1970 to 24% in 1981. Because of the significant increases in international patents issued to Japan, its AC industry will be further analyzed.

The U.S. Department of Commerce delineates a future pattern of Japanese domination of this industry as follows: "If things continue as they are now, our assessment is that the United States will fall behind Japan in the field of advanced engineering ceramics. Our reasons . . . are as follows:

- Japanese domination of the electric components portion of the advanced ceramics industry;

- Japanese domination of the supply of advanced ceramic powders;

- The greater and more organized R&D effort currently being undertaken in Japan;

- Initial performance/cost characteristics of Japanese demonstration products;

- Japanese reputation for investing in long-term product-market development and accepting short-term losses;

- The Japanese record in developing and implementing superior commercial manufacturing processes and process technologies."

Japan has claimed much of the world market, as shown in Table 12-9. The integrated circuit packaging market is now controlled by the Japanese, who are estimated to produce 80 to 90% of total world AC production. Kyocera (a Japanese firm located in San Diego) and IBM dominate AC integrated circuit packaging within the U.S., with Kyocera claiming 70% of the shipments.

TABLE 12-9

PRODUCTION OF ADVANCED CERAMIC PRODUCT LINES, 1980

PRODUCT LINE (1972 $)	JAPAN PRODUCTION (MILLION $)	% OF WORLD MARKET	WORLD PRODUCTION (MILLION $)
CERAMIC POWDERS	$ 72.9	52	140.1
INTEGRATED CIRCUIT PACKAGING	302.7	61	493.2
CAPACITORS	182.2	43	420.3
PIEZOELECTRICS	165.3	91	182.2
THERMISTOR/VARISTORS	70.1	63	112.1
FERRITES	213.0	79	269.0
GAS/HUMIDITY SENSORS	2.8	11	25.2
TRANSLUCENT CERAMICS	11.2	44	25.2
CUTTING TOOLS	70.1	12	574.5
STRUCTURAL CERAMICS	67.3	48	140.1
TOTAL	**1157.6**	**49**	**2381.9**

SOURCE: GEORGE B. KENNEDY AND H. KENT BOWEN, "HIGH TECH CERAMICS IN JAPAN - CURRENT AND FUTURE MARKETS" AMERICAN CERAMIC SOCIETY BULLETIN, MAY 1983

Production figures on IBM are not available because of the company's vertical integration. The world market for AC packaging, expected to experience the most growth in the electronic AC capacitor and resistor markets, is currently evenly split by the U.S. and Japan worldwide. Japan has gained its advantage in AC electronic components by using a superior, large-scale manufacturing process which results in lower production costs. Currently, IBM is the only U.S. firm that is competitive in the development of AC electronic components.

Trends in world market shares in AC engineering products (cutting tools, wear parts, heat engine parts) have not been established yet because of the small amounts of commercial production that have occurred. Japan is currently the dominant world supplier of pure ceramic powders from which these AC products are made. When large-scale commercial production of AC engineering products begins (projected to be before 1995), competition will be based on quality and price. The quality of AC engineering products is judged by thermal properties, hardness, corrosion resistance, and predictability of catastrophic failure. These products give no indication of failure through deformation, but instead disintegrate into smaller pieces, as opposed to conventional materials, which show signs of wear.

Role of Technology in the Long-Term Strategic Outlook

The AC products industry is definitely in the sunrise stage of development, as shown by its predicted growth in Table 12-7. New proposed technologies for the industry can be separated into advanced ceramic electronic components and advanced ceramic engineering products. The theory behind these technologies is discussed in Section E.1. Applications of these new technologies to various industries are discussed here and shown in Table 12-10.

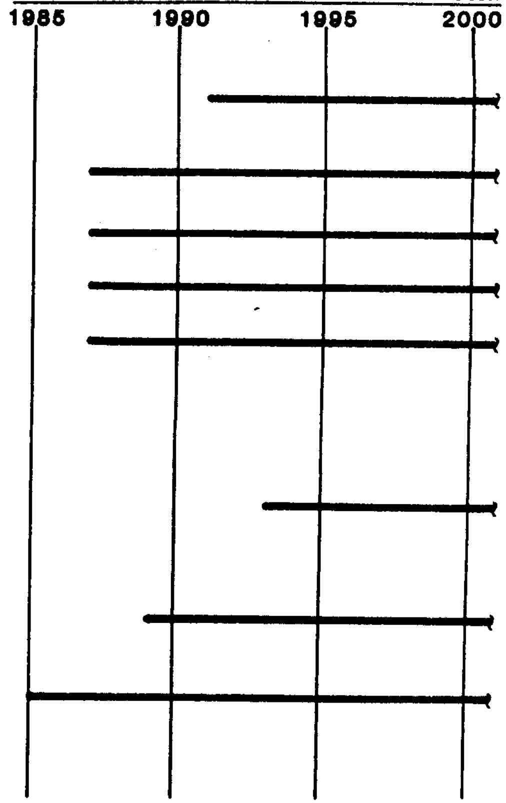
The electronic components and applications of advanced ceramic technology are as follows:

TABLE 12-10

APPLICATIONS OF ADVANCED CERAMIC TECHNOLOGY

APPLICATION	DESCRIPTION	PRINCIPAL IMPACT
ELECTRONIC APPLICATIONS		
• CAPACITORS	ADVANCED CERAMIC CAPACITORS MORE EFFICIENT CAPACITORS	INEXPENSIVE, SMALLER
• INTEGRATED CIRCUIT PACKAGING	FITTING IC CHIPS INTO CIRCUIT BOARDS	HIGHER PERFORMANCE AND RELIABILITY
• RESISTORS	ADVANCED CERAMIC THERMISTOR	IMPROVED CONTROL
• SENSORS	GAS AND TEMPERATURE SENSORS	BETTER CONTROL
• MAGNETIC COMPONENTS	PERMANENT MAGNETS, MEMORY UNITS, RADIO CIRCUIT ELEMENTS	SMALLER SIZE, LOWER COST
ENGINEERING PRODUCTS		
• HEAT ENGINE APPLICATIONS	IMPROVED PISTON ENGINES, CERAMIC ADIABATIC DIESEL ENGINE, CERAMIC GAS TURBINE ENGINE	INCREASED FUEL EFFICIENCY, MORE POWERFUL ENGINES
• CUTTING TOOLS	ADVANCED CERAMIC CUTTING EDGES EASIER USE OF ROBOTIC CUTTERS	HIGHER CUTTING SPEEDS
• WEAR PARTS	BEARINGS, SEALS, AND NOZZLES TECHNIQUES IN SOME INDUSTRIES	IMPROVE MANUFACTURING

APPROXIMATE ERA OF SIGNIFICANT DIFFUSION



SOURCE: U.S. DOC/IAD

- **Capacitors**--Multilayer ceramic capacitors are valued for their low capacitance levels, high dielectric constant, high resistivity, and low leakage. They are used in consumer electronic products, computers, telecommunications equipment, and scientific instruments. Cost, size, and speed of these capacitors will affect their future market. Major cost reduction can be achieved through the use of base metals (nickel, lead, and tin) in production as opposed to the noble metals (gold, platinum, palladium, and silver) currently being used. Noble metals currently account for 35% of the total cost of a multilayer ceramic capacitor. Reduction in capacitor size and an increase in capacitance value will increase the market share. Volumetric efficiency can be increased by increasing the dielectric constant, reducing the number of dielectric layers, or decreasing the thickness of dielectric layers. Use of new dielectric materials (lead, iron, tungsten, and lead iron niobate), better controlled processing parameters, increased automation, and improvements in ceramic powder purity will have to be used in order to meet this need. The speed of advanced ceramic capacitors (to be compatible with higher speeds of future integrated circuits) can be increased through the use of ceramic chip capacitors. These chip capacitors need to be standarized by size in order to gain wide market acceptance.

- **Integrated Circuit Packaging**--Advanced ceramic integrated circuit (IC) packaging is used to fit the semiconductor chip into larger circuit boards. A suitable operating environment within the computer or electronic device is produced by advanced ceramic IC packaging. Currently, the military is the primary user of ceramic IC packaging. The most promising ceramic IC packaging being developed is based on multilayer ceramic sub-

strates, consisting of layers of ceramic insulators alternating with conductor circuitry to form high-density wiring packages. As with ceramic capacitors, increased market share applications will depend on cost, size,and speed.

- **Resistors**--The use of ceramic thermistors should find increasing use as heat sensors in automobiles, to supply exhaust temperature data important to fuel efficiency, and in microwave and gas ovens.

- **Sensors**--The use of advanced ceramics in sensors is due to the semiconducting properties of ceramics, which allow them to transmit current only under certain conditions.

- **Magnetic Components**--AC materials with magnetic properties are used in permanent magnets, memory units, and circuit elements. They are derived from iron oxides combined with one or more metals (nickel, manganese, and zinc).

Advanced ceramic technology includes the following engineering applications:

- **Heat Engine Applications**--Advanced ceramics in heat engines will probably be used first in standard vehicular piston engines as components in cylinders, pistons, and turbochargers because major changes in production lines and engine technology will not be required for these applications. The major reason for using ceramic engines is their increased system performance, improved wear capability and lower weight. Critical flaws will also be easier to control. Turbocharger rotors are the most significant near-term item of an advanced ceramic component substitution. Ceramic

rotors are made from sintered silicon carbide. Research in ceramic turbocharger rotors is being conducted with private money, as opposed to most other heat engine applications which are government funded. Near-term ceramics substitution of other piston engine components include pistons and piston rings, cylinder liners and heads, valve lifters, and combustion chambers. Total ceramic piston engines are unlikely because they do not offer substantial gains in fuel economy or power production to warrant mass production. However, there are new vehicular engine designs which do offer significant gains in fuel economy and power production. These include the adiabatic diesel engine, which is made possible through the use of advanced ceramics. As compared to the conventional diesel engine, energy loss can be reduced by 50%, fuel consumption by 25%, and power can be increased significantly in the adiabatic diesel engine. These engines use thermal energy, normally lost to the coolant and exhaust systems, to make power through the use of turbomachinery. Use of a ceramic combustion chamber, (operating at high temperatures and reducing heat loss) with a turbocompound system, recovers the heat energy of the exhaust gases and transfers them to the crankshaft. Improved fuel economy and greater engine reliability is the result. The U.S. Army Tank Automotive Research and Development Command has been doing research in this area since 1976. Use in military and civilian heavy-duty trucks will come before use in automobiles.

Gas turbine engine use in vehicles became feasible in the 1960s with the development of advanced ceramic materials. Previously, the expense of the superalloys and their inability to withstand the high-operating temperatures prevented this development. AC gas tur-

bine engines alleviate the problem of expensive alloys, provide high temperature capabilities, and reduce wear on engine parts. Advantages of the turbine engine include improved fuel economy, lower engine weight, reduced maintenance, improved performance, and less pollutants. Currently the Department of Defense Advanced Research Projects Agency (DARPA) funds four R&D programs dealing with AC turbine engines. Stationary AC gas turbine engines are also being developed. The use of these engines in aircraft will be the last to be implemented, because of the high-performance needed and high-risk involved.

- **Cutting Tools**--Recent advances in AC materials and processing have made them competitive with high-speed steel and carbide cutting tools. Hardness, chemical stability, and heat resistance are all characteristics which give AC cutting tools an advantage. Ceramic materials are superior for cutting highly abrasive materials due to their resistance to wear, and are more effective for cutting at high speeds due to their resistance to heat. Resistance to thermal shock is one area where AC cutting tools are lacking because of their brittleness. Cutting tool use is currently very limited as compared to the potential market. Technological advances in the area of brittleness and thermal shock resistance (as compared to carbide machine tools) are needed before cutting tools can claim a substantial market piece. Silicon nitrate-based materials are considered to have a much greater potential than aluminum oxide ceramics, which have been available for 30 years. Alloying ceramic material with zirconia or titanium is being tried to improve fracture toughness. Unmanned machining (robotics) favors AC cutting tools because of the stiffness and long-life of the ceramic inserts.

- **Wear Part Applications**--Ball and roller bearings for high-performance applications made of AC materials (silicon nitride in particular) are now finding limited use in industrial machinery, for corrosive oil, gas, and chemical processing, and are being researched for use in automobile and aircraft engines. Improved processing methods have allowed densification of silicon carbide and silicon nitride, which has increased their tolerance to point or stress loading. The light weight, heat resistance, and wear resistance of ceramic bearings are major advantages over conventional (tungsten/steel) bearings. Their light weight makes the centrifugal load lower, thereby improving fatigue life and high-speed performance. Conventional tool steel (the highest temperature resistant material now in use) softens excessively after being exposed to high temperatures for long periods of time. Higher temperature resistant bearings (i.e., advanced ceramic bearings) will be necessary for future high-speed industrial machinery. Advanced ceramic pump seals are used in sand slurries, chemical processing, and oil and gas recovery. Currently they are the most widely used AC product in the wear parts category. The same properties that make AC products useful in other applications (hardness, low friction, high resistance to corrosion, high temperature capability) make them useful in pump seals. Temperature characteristics of advanced ceramics have made them perfect for this application, because of the need to dissipate heat at the surface of the seal. Stability of shape when heated quickly (dimensional stability) is also a critical feature of advanced ceramics. Sandblast nozzles are now being made of advanced ceramics due to the need for nozzles with high wear capabilities and abrasion resistance.

Table 12-11 lists the strategic materials that advanced ceramics could replace. Clearly, advanced ceramics will be a key to the future technological development of many industries.

Conclusion

The advanced ceramic industry is clearly experiencing rapid growth. Advances in AC technology are continuing in the areas of ceramic powder production, integrated circuit packaging, capacitors, cutting tools, wear parts, engine design, and other advanced ceramics products.

Industry shipment of AC products are expected to increase nearly ten fold in the next 20 years. AC products could replace the following strategic materials: tungsten, cobalt, nickel, chromium, molybdenum, manganese, titanium, platinum and palladium, columbium, and tantalum.

Currently, the U.S. and Japan are virtually equal with regards to technology in the field. If current conditions remain unchanged, U.S. will fall behind Japan in AC technology. According to the U.S. Department of Commerce, there are two categories of technology push and market pull. The technology push option involves:

- Federal R&D expenditures increased for advanced engineering ceramics. The money should be directed at solving the AC problem of catastrophic failure and at finding cost-effective manufacturing techniques.

- Provide an improved technology transfer function of AC technology from military and space applications to the private sector.

- Increase private R&D on AC technology through federal incentives such as tax incentives, matching funds, and low-interest loans.

TABLE 12-11

POSSIBLE ADVANCED CERAMICS SUBSTITUTION
FOR STRATEGIC MATERIALS

MATERIAL	SYMBOL	APPLICATION WHERE CERAMICS MAY REPLACE THE MATERIAL	TECHNOLOGICAL BARRIERS FOR CERAMICS
TUNGSTEN	W	WEAR PARTS (LINERS, PADS, NOZZLES, BEARINGS, GATES, SLIDES, VALVES, SEALS).	DEMONSTRATION, SCALE UP, COST
COBALT	Co	DIESEL COMBUSTION PARTS	DEMONSTRATION, COST
		TURBOCHARGER ROTORS	N/A
		HEAT RECOVERY SYSTEMS	N/A
NICKEL	Ni	DIESEL COMBUSTION PARTS	DEMONSTRATION, PROPERTIES; MAINTENANCE OF CURRENT CREEP AND OXIDATION LEVELS, COST
		TURBOCHARGER ROTORS	N/A
		HEAT RECOVERY SYSTEMS	FABRICATION AND PERFORMANCE INNOVATIONS, DEMONSTRATION, COST
		CHEMICAL WARE (ANTI-CORROSION PIPING, VALVES, SEALS, ETC., GASIFIER COMPONENTS, COATINGS)	N/A
CHROMIUM	Cr	HEAT ENGINES	DEMONSTRATION, PROPERTIES, COST
		CHEMICAL WARE	N/A
		HEAT EXCHANGERS	FABRICATION, PERFORMANCE, DEMONSTRATION, COST
MOLYBDENUM	Mo	HEAT RECOVERY SYSTEMS	N/A
MANGANESE	Mn	HEAT ENGINES	DEMONSTRATION, PROPERTIES, COST
TITANIUM	Ti	WEAR PARTS	DEMONSTRATION, SCALE-UP, COST
		CUTTING TOOLS AND ABRASIVES	ACHIEVE HARDNESS, NEW COMPOSITES
		HEAT APPLICATIONS	N/A
PLATINUM AND PALLADIUM	Pt,Pd	CHEMICAL WARE	N/A
BERYLLIUM	Be	STRUCTURAL MEMBERS (FIBER REINFORCED SPARS; TILES; CASTINGS)	INNOVATION IN COMPOSITES, ORGANO-CERAMICS TECHNOLOGY DEVELOPMENT
COLUMBIUM (NIOBIUM)	Nb	HIGH-TEMPERATURE APPLICATION	FABRICATION, PERFORMANCE, DEMONSTRATION
TANTALUM	Ta	HIGH-TEMPERATURE APPLICATION	COSTS, HARDNESS POTENTIAL
		WEAR PARTS	N/A

N/A - NOT AVAILABLE.

SOURCE: L.R. JOHNSON, ET AL., "A STRUCTURAL CERAMIC RESEARCH PROGRAM: A PRELIMINARY ECONOMIC ANALYSIS," ARGONNE NATIONAL LABORATORY, MARCH 1983

- Improve the capacity of the U.S. to transfer foreign scientific advances in the AC field. This is one particular area where Japan is much better equipped.

- Stimulate universities and colleges to train advanced ceramics engineers by offering them federal funds for their programs.

The market pull option includes:

- To purchase federal items on the basis of their content of advanced ceramic products. This could include military items, automobiles, and office computing equipment.

- The Bureau of Standards must set reliability standards in AC products to insure quality.

- To provide AC producers with liability insurance due to the problem of AC catastrophic failure.

The primary need for advanced ceramic research, however, is in the areas of solving the catastrophic failure problem and in finding a cost-effective method of production.

B.12 "STONE, CLAY AND GLASS" (SIC 32)

TABLE OF CONTENTS

SOURCES: U.S. DOC/BOC:

Statistical Abstract of the U.S. 1982-83

Census of Manufacturers, 1977

Annual Survey of Manufacturers, 1981

EOP/DMB:

Standard Industrial Classification Manual, 1972

U.S. DOC/BIE:

Industrial Outlook, 1984

U.S. DOL/BLS:

Value-Line Investment Survey, 1984

Moody's Handbook, 1984

LIST OF TABLES

B.13 "RUBBER AND MISCELLANEOUS PLASTICS PRODUCTS" (SIC 30)

The rubber and miscellaneous plastics products subsector, SIC 30, whose value added accounted for 2.9% of the manufacturing sector's contribution to GDP in 1980, comprises the 14th largest manufacturing industry (in this study, the apparel and other textile products subsector, SIC 23, the 13th largest manufacturing industry will not be covered). The subsector is characterized by:

- A high degree of fragmentation. Out of a total of approximately 18,000 establishments, 13,000 employ less than 20 persons (1977).

- A low labor productivity of $17,988 per employee or $9.37 per employee hour (1980, 1972 $), ranking this subsector fourteenth among the nation's 20 manufacturing subsectors. A compound annual labor productivity growth rate average of -0.6%/year from 1972 to 1980 ranks this subsector last. The labor productivity for the comparable Japanese subsector was $11,508 per employee year or $5.99 per employee hour (1980, 1972 $), ranking this subsector eleventh among Japan's 20 manufacturing subsectors. The compound annual labor productivity growth rate for the Japanese subsector averaged 4.4%/year from 1972 to 1980, ranking this subsector sixteenth.

- An average capital investment base relative to other subsectors within the manufacturing sector. Capital investment amounted to $15,962 in total assets per worker, ranking eighth in terms of (depreciated) fixed assets (1980, 1972 $). New yearly capital expenditures were $1,648 per employee (1980, 1972 $), ranking eleventh in the manufacturing sector. Total capital productivity, measured as dollars of added value output per dollar investment, was 0.82 (1981).

- An average R&D program. For the subsector as a whole, R&D expenditures amounted to $0.4 billion (1980, 1972 $), ranking this subsector eighth among the 20 manufacturing subsectors. R&D expenditures were equivalent to 2.9% of the value added by the subsector in 1980.

Table 13-1 shows the major products of each subdivision of the rubber and miscellaneous plastics products industry, with their share of the subsector's contribution to GDP in 1980 ranked in descending order. Table 13-2 summarizes the principal economic measures of these subdivisions.

One subdivision--miscellaneous plastics products (SIC 307 or 3079) which consists of manufactured plastic products of all types with the exception of plastic footwear and plastic hose/belting--accounted for 64% of the subsector's output in 1980. Because this subdivision considerably dominates the other subdivisions within this industry, it has been selected for analysis in order to assess long term technology needs.

B.13.1 MISCELLANEOUS PLASTICS PRODUCTS (SIC 307)

The total plastics industry produced $54 billion in shipments in 1983. The miscellaneous plastics products subdivision accounted for $37 billion of shipments or 68%; the remaining 32%, classified as plastics materials and resins (SIC 2821), constitutes captive production or the self-manufacture of plastic products to be consumed within other major industry groups. Examples of the latter are the automotive industry, food packaging materials, and toy manufacturers. Miscellaneous plastics products are associated with all other plastic products industries (with the exception of plastic footwear and plastic hose/belting).

TABLE 13-1

CLASSIFICATION OF MAJOR PRODUCTS OF THE RUBBER AND MISCELLANEOUS PLASTICS PRODUCTS INDUSTRY (SIC 30) AND CONTRIBUTION TO SUBSECTOR IN 1980

SIC CODE	SUBDIVISION DESIGNATION AND TYPICAL PRODUCTS	% CONTRIBUTION
307	**MISCELLANEOUS PLASTICS PRODUCTS**	64.4
	PLASTIC PRODUCTS OF ALL TYPES EXCEPT PLASTIC FOOTWEAR AND PLASTIC HOSE/BELTING	
301	**TIRES AND INNER TUBES**	18.0
	RUBBER INNER TUBES, TIRES, AND TIRE REPAIR MATERIALS	
306	**OTHER FABRICATED RUBBER PRODUCTS**	12.0
	INDUSTRIAL AND MECHANICAL RUBBER GOODS, RUBBERIZED FABRICS AND VULCANIZED RUBBER CLOTHING	
304	**RUBBER AND PLASTICS HOSE AND BELTING**	4.1
	AUTOMOBILE, GARDEN, VACUUM AND OTHER RUBBER AND PLASTIC HOSES AND BELTS	
302	**RUBBER AND PLASTICS FOOTWEAR**	1.4
	RUBBER AND PLASTIC BOOTS, SHOES, AND OTHER FOOTWEAR	
303	**RECLAIMED RUBBER**	0.1
	RECLAIMED RUBBER PRODUCTS OF ALL TYPES	
30	ALL RUBBER AND PLASTIC PRODUCTS	100.0

SOURCES: U.S. DOC/BOC: STATISTICAL ABSTRACT OF THE U.S. 1982-3
EOP/OMB: STANDARD INDUSTRIAL CLASSIFICATION MANUAL, 1972

TABLE 13-2

SUBDIVISIONS AND CHARACTERIZATION OF RUBBER AND MISCELLANEOUS PLASTICS INDUSTRY (SIC 30) DURING 1980, IN 1972 DOLLARS

SUBDIVISION	PERCENTAGE CONTRIBUTION	NUMBER OF EMPLOYEES (1,000)	NUMBER OF ESTABLISHMENTS[a]			GROSS VALUE OF FIXED ASSETS/ ($/EMPLOYEE)	NEW CAPITAL EXPENDITURES ($/EMPLOYEE)	LABOR PRODUCTIVITY ($/EMPLOYEE)
			TOTAL	LESS THAN 20 EMPLOYEES	100 OR MORE EMPLOYEES			
ALL RUBBER & MISC. PLASTICS (30)	100	703.2	11,943	6,649	1,554	15,967	1,648	17,988
TIRES AND INNER TUBES (301)	18.0	87.2	200	74	94	28,122	2,126	26,196
RUBBER, PLASTICS FOOTWEAR (302)	1.4	18.0	84	34	34	4,132	389	9,581
RECLAIMED RUBBER (303)	0.1	0.6	21	12	3	38,112	747	22,979
RUBBER AND PLASTICS HOSE, BELTING (304)	4.1	32.4	146	43	63	22,286	2,064	15,856
FABRICATED RUBBER PRODUCTS (306)	12.0	94.9	1,280	659	237	11,354	950	16,006
MISC. PLASTICS PRODUCTS (307)	64.4	470.1	10,212	5,827	1,123	14,626	1,722	17,328

[a] 1977

SOURCE: U.S. DOB/BOC: CENSUS OF MANUFACTURES, 1977
U.S. DOC/BOC: ANNUAL SURVEY OF MANUFACTURES, 1981

Business and structural profiles of the miscellaneous and plastic products subdivision are presented in Tables 13-3 and 13-4, respectively. Table 13-3 shows that industry shipments expressed in constant 1972 dollars, have increased 55% in eleven years, from $10.7 billion in 1972 to $16.6 billion in 1983. Employment rose steadily up to 1979, after which it stabilized at a slightly lower level. Labor productivity, i.e., output per employee hour, rose from 1972 to 1977, and has stabilized at that level.

Table 13-4 shows that the miscellaneous plastics products industry is highly fragmented; 75% of its establishments employ less than 20 persons. A typical manufacturer in this industry earned a net income of 3% after taxes in 1981 on sales of about $5 million. The typical plastics fabricator is a small, independent business with a potential for modular operations and incremental expansion. Its finished product is dominated primarily by the cost of input materials (49%), and secondarily by manufacturing and other labor (21%) costs. In 1979 and 1983, the value of exports in this industry was nearly twice the size of imports.

The dominant constraint in the miscellaneous plastics products industry is cost. Because plastic is a petrochemical-based product, the cost of plastic is dependent on the cost of oil.

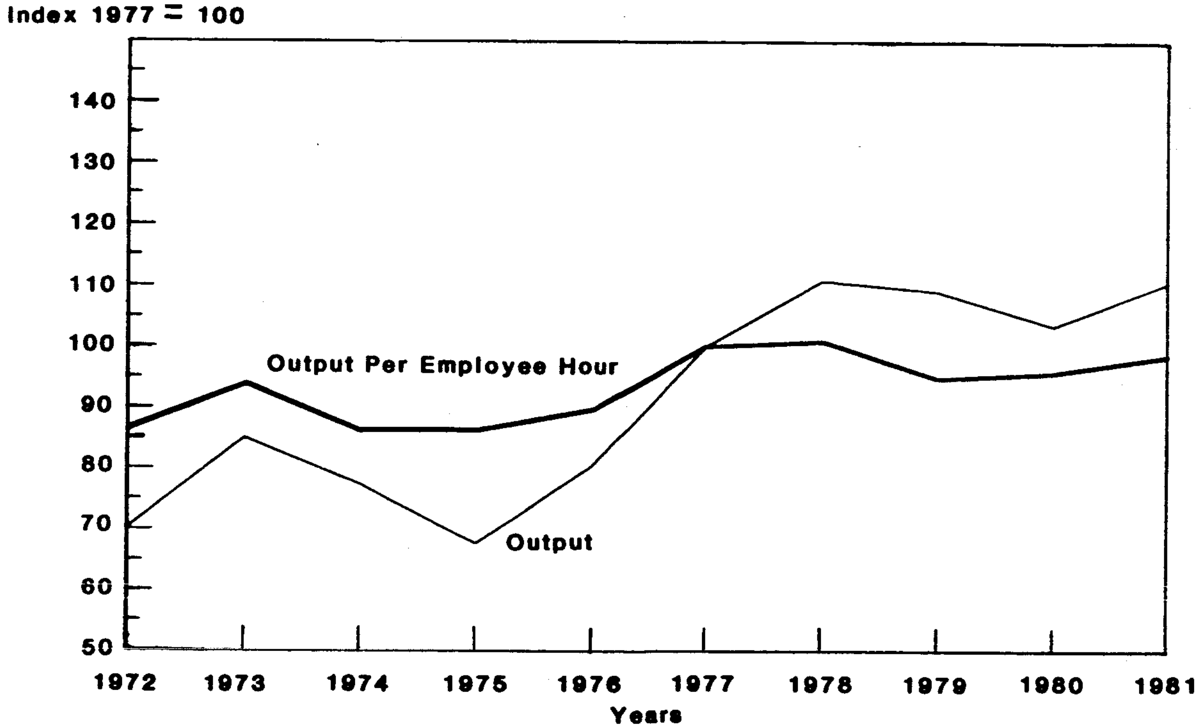
Key Growth Influences in the Miscellaneous Plastic Products Industry

The use of fabricated plastic parts has undergone a significant change in focus over the last five years. Whereas the early growth of the industry was driven by the low cost substitution of plastic parts for natural materials, advances in polymer and processing technologies in the 1980s have resulted in the production of plastic parts with superior performance to natural

TABLE 13-3

BUSINESS PROFILE OF THE
MISCELLANEOUS PLASTICS PRODUCTS INDUSTRY (SIC 307)

SHIPMENTS (BILLION $)	1972	1977	1979	1981	1983	1984 EST
CURRENT $	10.7	23.7	29.1	34.1	37.0	--
1972 $	10.7	14.6	15.6	15.7	16.6	17.9
TOTAL EMPLOYMENT (THOUSANDS)	346.9	453.7	487.7	469.5	452.2	465.0



Source: BLS Data

PLANT CAPACITY UTILIZATION, 1982 %	64.0
PRETAX PROFIT, 1981, %	4.2
RETURN ON EQUITY, 1983, %	4.7
VALUE OF PLANT, 1976, CURRENT $, BILLION	7.3

	1977	1981
NEW CAPITAL EXPENDITURES, CURRENT $, BILLION	1.2	1.6

SOURCES: U.S. DOC/BIE: 1984 U.S. INDUSTRIAL OUTLOOK
U.S. DOC/BOC: CENSUS OF MANUFACTURES, 1977
U.S. DOL/BLS
VALUE-LINE INVESTMENT SURVEY, 1984

TABLE 13-4

STRUCTURAL PROFILE OF THE
MISCELLANEOUS PLASTICS PRODUCTS INDUSTRY (SIC 307)

ESTABLISHMENTS (1977)

(CATEGORIZED BY NO. OF EMPLOYEES)

SMALL (< 20)	5,827
INTERMEDIATE (20 - 1000)	4,368
LARGE (> 1000)	17
TOTAL (8,824 COMPANIES)	10,212

REPRESENTATIVE FIRMS (1983)

NAME	TOTAL REVENUES (MILLION $)
RUBBERMAID, INC.	436.4
WEST CO., INC	190.4
SEALED AIR CORP.	124.5

PRODUCTION COST	MFG. LABOR	OTHER LABOR	MATERIALS	ENERGY	CAPITAL
DISTRIBUTION, 1977	14%	7%	49%	2%	28%

R&D EXPENDITURES

CURRENT $, MILLION, 1981	500

INTERNATIONAL TRADE	1972	1979	1983
VALUE OF EXPORTS, CURRENT $, BILLION	0.38	1.5	1.9
VALUE OF IMPORTS, CURRENT $, BILLION	0.25	0.8	1.0

SOURCES: U.S. DOC/BIE: 1984 U.S. INDUSTRIAL OUTLOOK
U.S. DOC/BOC: CENSUS OF MANUFACTURES, 1977
MOODY'S HANDBOOK, 1984

materials (e.g., ceramics, metals, and wood). At the same time, the average cost of high performance resins has continued to drop through the use of alloying or blending with lower-cost commodity thermoplastics. The result, in many cases, is a lower-cost, higher-performing plastic part.

A second major growth influence in the plastics products industry is the key role that plastics fabrication plays in the rapidly-growing electronics industry, in areas as diverse as printed circuit boards and business machine housings.

Technology Trends In The Miscellaneous Plastics Products Industry

Most technological advances which impact the plastic products industry are developed outside the industry. For example, the packaging industry has been a leading proponent of the so-called "plastic can", a product being developed to replace the metal can in many food applications. The actual development process has involved packaging companies, plastic resin companies, equipment manufacturers and, of course, fabricators. In point of fact, the packaging company, equipment company, and resin manufacturer work out the details and the fabricator will "take orders" for producing the final product. Another second source of technical development is derived directly from equipment manufacturers, a group that has a vested interest in developing new and different equipment in order to obsolete "old" machines and maintain industry shipments.

This outside influence is typical of the plastic products industry, in which smaller fabrication companies do not have the budget or interest to take on any but the most elementary research and development projects. They prefer to leave this work to the larger resin and/or food packaging companies. In all probability, any significant product or process developments will come from these integrated companies.

Plastic fabrication processes which show the highest level of future activity include:

- Resin transfer molding
- Twin screw extrusion and compounding
- Reaction injection molding (RIM)
- Sheet molding compound (SMC) and injection molding of bulk molding compound
- Pultrusion
- Thermoforming
- Sheet and film co-extrusion and lamination, and
- Injection blow-molding and co-extrusion blow-molding

All of these technologies are being pursued today and many are already part of viable commercial operations. Future development efforts are likely to be focused on such areas as cold stampable polymers, high-strength structural composites, super-high temperature polymer processing, flame-retardant plastic products, biodegradable plastic parts, and so on. However, it is unlikely that any of these development efforts will be supported by the fabrication industry itself. These projects will be undertaken by resin manufacturers, end users, or outside third parties.

Long-Term Technological Assessment of the Miscellaneous Plastics Products Industry

Over the next five to 15 years, the miscellaneous plastics products industry should experience a solid, but cyclical growth rate as the redefined role of substitution and the growth of the electronics industry drive plastic products demand. In-house fabrication together with selected custom fabricators will support most of these technology developments. However, these developments will be more likely driven by the end user rather than the fabrication process itself. In the longer term, as the needs of end users become more sophisticated and product and

process technology becomes more proprietary, the role of the independent fabricator in areas outside of commodity applications could be decreased.

The technological challenge in this industry will continue to be the development and fabrication of synthetic materials with superior performance and light weight--so called high performance structural composites. Superior performance will depend on two factors: 1) the material used, a function of the up-stream industries; and 2) the method of "putting materials together." Current research in these areas is driven by the automotive and air transportation industries. This research will incorporate developments from all segments of the chemical, polymer and fabricated products industries and will have wide-ranging applications. For example, in the long term, synthetic material could go a long way towards replacing conventional building materials.

Generally, the long-term technological challenge will be to derive the same performance from synthetic materials--cubic inch for cubic inch--that is currently possible from conventional materials such as steel and wood. Pound for pound, synthetics are already superior to natural materials in many end uses, and, the inventory of useable synthetic materials is quite large: 50 unique polymers, a dozen or so fibers, and an almost unlimited number of fillers and additives. It is most likely, therefore, that future breakthroughs in the development of structural synthetic materials will derive from selecting the right materials among a multitude of choices and fabricating them in such a way as to achieve a unique performance.

Assuming that both the materials and a structure are available, key technologies will also depend upon the designing of machines to perform a particular task. An example which received considerable publicity was the design and fabrication of a structural skeleton for a space station. Work is currently being performed on an epoxy-impregnated carbon-fiber ribbon, which can

be fed into a fabricating machine and converted into a structural "beam". This lightweight, yet strong material, and the process associated with its conversion to a useful product, could greatly reduce the cost of building in space.

In addition, new technologies need to be developed in the adhesives industry. As synthetic building materials emerge, new ways must be developed to hold the pieces together--quite likely mechanical fasteners will give way to chemical fasteners or adhesives.

Many of these technology issues have already surfaced in the aerospace and automotive industry as engineers have sought improved fuel economy through weight reduction. For example, the relatively simple task of aligning automotive body parts for welding became nearly impossible when the industry started using plastic with pre-drilled holes--the parts would never line up exactly with the holes. A potential solution to this problem is to use adhesives. However, there is clearly a long way to go before we can efficiently produce these products with synthetic materials.

In the future, it will become more difficult to distinguish between rubber and plastic products. Alloys and blends of elastomers and plastic resins are common today and will increase over time. Plastic resins provide stiffness for rubber products and elastomers provide impact resistance and flexibility for plastic products. Both are made from synthetic resins which are derived from many of the same basic molecules. Thus, the final part of this challenge will be to look beyond conventional industry boundaries in search of all kinds of materials which can be combined with rubber and plastic to create new structural composites.

Conclusion

The miscellaneous plastics products industry is one of the fastest growing industries in the U.S., although at present it is the smallest (in-terms of value-added contribution to GDP) industry reviewed in this report. In the future, the industry is expected to continue to grow faster than the U.S. economy in general as plastics are combined with textiles, fiberglass, rubber, and carbon fibers to produce composites to replace currently-used conventional materials. The new composite materials will be found in a wide range of products ranging from aircraft and automobiles to buildings.

The miscellaneous plastics products industry has an average R&D program but augments developments that arise with research advances developed by other industries.

The needs of the industry can be categorized into two areas:

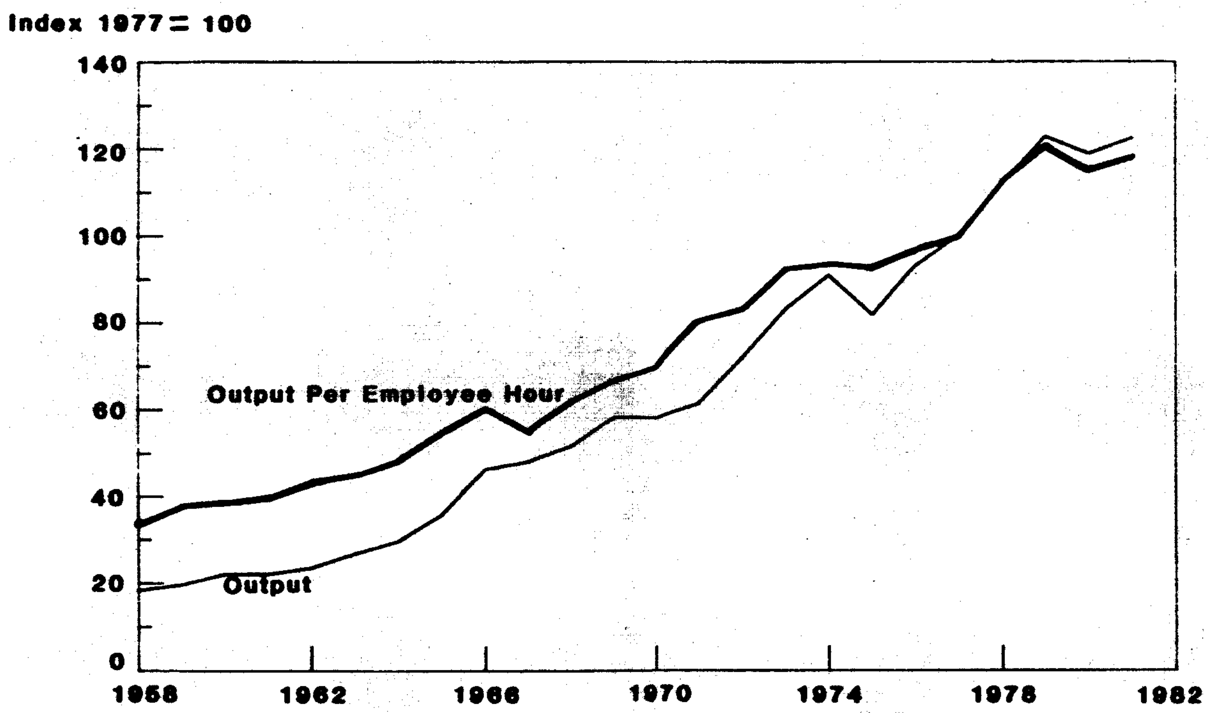
- Development of synthetic materials to replace wood and metal as structural building materials, and to replace or be blended more with rubber. Currently, this development is dependent upon research results from the chemical, polymer, and fabricated products industries.

- New technologies are needed to develop chemical adhesives to replace currently used mechanical fasteners.

TABLE 11-11

BUSINESS PROFILE OF THE PHOTOGRAPHIC EQUIPMENT AND SUPPLIES INDUSTRY (SIC 386)

SHIPMENTS (BILLION $)	1972	1977	1979	1981	1982	1983
CURRENT DOLLAR	5.6	9.9	13.4	16.9	18.0	18.1
1972 DOLLAR	5.6	7.7	9.5	9.3	9.9	9.9
TOTAL EMPLOYMENT (THOUSANDS)	96.0	111.7	114.1	114.2	116.7	108.7



Source: Unpublished BLS Data

AGE OF PLANT, LEADING FIRMS, 1983 — 7 YEARS

NEW CAPITAL EXPENDITURES, 1983, MILLION $ — 322.7

SOURCES: U.S. DOC/BIE: 1984 U.S. INDUSTRIAL OUTLOOK
U.S. DOC/BOC: CENSUS OF MANUFACTURES, 1977
VALUE-LINE INVESTMENT SURVEYS, 1984
U.S. DOL/BLS

TABLE 11-12

STRUCTURAL PROFILE OF THE PHOTOGRAPHIC EQUIPMENT AND SUPPLIES INDUSTRY (SIC 386)

ESTABLISHMENTS (1977) (CATEGORIZED BY NO. OF EMPLOYEE)		LEADING FIRMS (1983) NAME	DOMESTICALLY GENERATED SALES (MILLION $)
SMALL (<20)	515		
INTERMEDIATE (20-1000)	250	EASTMAN KODAK COMPANY	5065
LARGE (>1000)	15	XEROX CORPORATION	3795
		POLAROID CORPORATION	728
TOTAL (702 COMPANIES)	780	FOTOMAT CORPORATION	260

	MFG. LABOR	OTHER LABOR	MATERIALS	ENERGY	CAPITAL
PRODUCTION COST DISTRIBUTION, 1977	9%	10%	32%	1%	48%

SHIPMENTS ACCOUNTED FOR BY FOUR LARGEST COMPANIES 72%

SOURCES: U.S. DOC/BOC: CENSUS OF MANUFACTURES, 1977
VALUE-LINE INVESTMENT SURVEYS, 1984

TABLE 11-13

DOMINANT CONSTRAINTS AFFECTING THE PHOTOGRAPHIC EQUIPMENT AND SUPPLIES INDUSTRY (SIC 386)

CONSTRAINT	PRINCIPAL IMPACT
FISCAL/MONETARY POLICY	STRONG U.S. DOLLAR LIMITS EXPORTS, HIGH INTEREST RATES LIMIT DOMESTIC INDUSTRIAL AND PROFESSIONAL SALES, WHILE CONSUMER SECTOR IS VULNERABLE TO LEVEL OF CONSUMERS' DISCRETIONARY INCOME.
CYCLICAL MARKET	MARKET CLOSELY TIED TO BUSINESS CYCLE AND PRODUCT INNOVATION CYCLE. END OF RECESSION AND INCREASED CONSUMER CONFIDENCE HELPS SALES.
INVESTMENT RISK	OVER 90% OF U.S. HOUSEHOLDS CURRENTLY OWN CAMERAS. GROWTH OF HARDWARE SALES IS MINIMAL COMPARED TO GROWTH IN THE FILM AND PHOTOFINISHING MARKETS, WHICH HAVE LOWER ROI.
LACK OF VERTICAL INTEGRATION IN CORPORATE STURTURE	HARDWARE IS TYPICALLY PURCHASED FROM HARDWARE MANUFACTURERS, FILM FROM MAJOR FILM MANUFACTURERS: LEADS TO BACKLOGS AND DIFFICULTY PROTECTING PATENTS.

Competitive Issues Affecting the Photographic Equipment and Supplies Industry

In the past few years, the industry has been developing a dichotomous market nature. Products are being developed for a silver imaging market and for a newer high-tech electronic imaging market, as opposed to a single "photo" market. Each of these markets produces products for both amateur/consumer use and industrial use.

Silver Imaging

The silver imaging market retains the traditional flavor of the photographic industry, developing and producing devices that use silver halide in an emulsion method for producing high quality images. These include the traditional products:

- 35mm cameras--both single lens reflex (SLR) and lens/shutter (nonSLR),
- cartridge cameras,
- disc cameras,
- instant photography,
- photographic film, and
- other camera accessories.

35mm Camera Market--Imports provide virtually the sole source of both single lens reflex (SLR) and lens/shutter (nonSLR) 35mm cameras. These cameras account for approximately one-fourth of the total U.S. still camera sales. Any meaningful analysis of this market must start with the realization that there is no longer a single 35mm market, but two markets: the 35mm SLR market and the 35mm lens/shutter market.

The first market, the SLR market, is a relatively high priced, sophisticated one, catering to professionals, serious amateurs and semi-involved amateurs. In the past several years, market growth has come from this last group of consumers, who are mainly affluent buyers with substantial amounts of disposable income.

This market has matured only slightly in recent years. Shipments of SLRs for 1983 were approximately 2.7 million cameras, up only slightly from the 2.6 million units shipped in 1982. This trends suggests that most of the potential SLR users have already been converted to actual users.

The lens/shutter (nonSLR) camera market shows the exact opposite trend. Shipments in 1983 soared to 1.4 million units, up 40% from 1982 and almost 150% over the half million lens/shutter cameras shipped in 1980. These sophisticated cameras have the point and shoot convenience of a box camera, with auto-wind, built-in flash, coated high-speed lens and automatic exposure control features. More importantly, the addition of sophisticated electronics was accompanied by the ability to produce these cameras at incredibly low prices. Selling prices of approximately $100 have created a mass market of amateur users who want the sophistication of SLR cameras without the high price. The lens/shutter camera will become increasingly popular in coming years.

Cartridge Cameras--Sales of 110 cartridge-loading cameras fell sharply in 1983, partially as a result of increased competition from disc cameras and 35mm lens/shutter cameras which offer considerable advantages for only slightly more money. Approximately 3.5 million cartridge-loading cameras were sold in 1983, down 12% from 1982 and 50% from 1981. The accelerated decline of this market may also be attributable to the fact that these cameras are sold in a market where better than 90% of the households have cameras. Many of the consumers in this market are blue collar workers who have been severely affected by the recession. Although the recession is officially over, its impact will linger for a while, especially in the area of luxury items. This lingering effect, together with the increasing popularity of the disc and lens/shutter models, will contribute to the decline and probable elimination of this market.

Disc Cameras--In 1982, disc camera shipments exceeded those of cartridge cameras despite the generally reduced demand for photographic equipment. Eastman Kodak, which developed the disc camera, supplied virtually all of the five million disc cameras shipped to U.S. retailers and the three million units to foreign customers, in 1982. However, in 1983, less than two years after its introduction, the disc camera was being produced in low cost versions by camera makers in Hong Kong, Taiwan, Japan and Germany. Domestic and foreign manufacturers together shipped between five and six million units to U.S. retailers.

Instant Photography--Consumer purchases of instant cameras are shrinking. Sales of instant cameras remained at approximately 3.5 million units for 1983, the same as in 1982, and down 1.5 million units from 1981. Japanese instant cameras and film, which reached foreign markets two years ago, have adversely affected U.S. foreign sales. Attempts to reverse this downward trend include the introduction of instant films with faster speeds and films that allow the separation of the print from the development backing. Other innovations include infrared light sensing and electronic prejudging of the amount of light needed. The identification of new markets in the technical and industrial areas should offer future growth for those instant cameras that have been previously introduced into the market. Since technology in this field has not advanced too rapidly, the existing units will certainly support the instant film industry.

Photographic Film--The value of sensitized photographic film and plate shipments was approximately $4.7 billion during 1983. Recent technological improvements include advances in image sharpness, grain and speed. For example, disc camera film uses a precisely calculated formula of color couplers to increase the development of silver halide crystals in lightly exposed areas, improving color contrast and sharpness.

U.S. manufacturers also introduced ISO 1000 film in 35mm format. This film, the world's fastest, allows for exposures under very low lighting conditions. The push to develop faster, more light sensitive films can be expected to continue for the next several years. The new transparency film technologies make possible the processing of slides and instant prints from slides in less than five minutes without darkroom facilities.

The Japanese have introduced their own disc films and improvements to existing color film lines. To attract attention to these products, Japanese suppliers have increased their advertising and promotional campaigns, including the sponsoring of major events such as the 1984 Los Angeles Summer Olympics.

Retail sales of photographic film have a direct bearing on photofinishing services. The increased number and variety of photographic films have helped to encourage an increase in the number of exposures, especially by amateur consumers. In 1983, exposures increased 6% to 11.4 billion, with 95% of consumers using color film. The new films should also increase the number of good exposures per roll which in turn encourages reprints and enlargements. Thus, increased film quality will continue to encourage growth in photofinishing services.

Other Camera Accessories--Two other major categories, electronic flash units and interchangeable lenses, also declined in 1983.

Electronic flash dropped from 3.0 million units shipped in 1982 to 2.5 million units in 1983. A prime reason for this decline is the incorporation of built-in flash units in most of the current lens/shutter (nonSLR) cameras, which should lead to more convenience and value and stimulate sales of the 35mm lens/shutter cameras.

While interchangeable lens shipments increased by 10% from 3.0 million units to 3.3 million for 1983, this was still below the record 3.4 million lenses shipped in 1981. Approximately, 60% of lenses sold are zoom lenses. Although significantly more expensive, one zoom lens can function in place of three or four fixed focal length lenses. Increased usage of zoom lenses will continue to affect the shipments of interchangeable lenses.

Electronic Imaging

The electronic imaging, or video, market has been entering a transition phase, from a small enthusiasts' market to a huge mass market. Hardware and software are becoming less expensive and easier to use. Thus, virtually every major photographic company is active in the electronic market as a producer of video cameras, as a marketer of video tapes or as the manufacturer of specialized products combining both silver-imaging and electronic imaging technologies.

Areas covered by electronic imaging include:

- video cassette recorders and tapes,
- video cameras and camcorders,
- microfiche, and
- photocopying.

Video Cassette Recorders and Tapes--As in the case of most video products, sales of video cassette recorders (VCR) and tapes reached record highs in 1983. Total VCR sales of 4 million units for 1983 doubled the 2 million units sold in 1982. Prerecorded tape sales increased from 6 million to 8 million units. Blank tapes experienced a dramatic increase in sales, from 28 million units in 1982 to approximately 50 million units in 1983.

All of these sales trends indicate that the video market will continue a rapid growth period. Another interesting aspect of the development of this market is the change in the average household income of the VCR consumer from $53,000 to $34,000, which indicates that the video market is moving into a truly "middle class" market with mass market growth potential.

Video Cameras and Camcorders--One of the more significant developments in the electronics imaging market was the introduction of an 8mm video camera-recorder system by Eastman Kodak. Introduced in January 1984 together with a complete set of video tapes, this product represents the full-scale entry of a major U.S. photographic company into the electronic imaging market.

Two compact "camcorder" models have been introduced together with a special cradle which provides recharging capability and playing facilities for the video tape. The more expensive "camcorder" model offers many of the conviences of the Super 8 movie cameras, including automatic focus and power zoom. The less expensive model has manual focus and fewer automatic features. This product is clearly aimed at Kodak's traditional "family" market, with its integrated design and easy-to-use features. However, the wide range of video tape formats being offered with the system also allow wide-range professional applications.

Tables 11-14 and 11-15 show the top ten foreign consumers of U.S. photographic goods and the top ten foreign suppliers of photographic goods to the domestic market, respectively. U.S. exports are spread relatively evenly among the top five consumers, but imports are not evenly distributed. Japan accounts for 71% of 1982 U.S. imports of photographic goods. Most imports are also showing very rapid growth rates, especially in comparison with the low growth rates of U.S. exports. Figure 11-6 reflect the recent foreign market activity. From this Table it is evident that the U.S. positive balance of trade has been declining at a rate of about 9.5% per year from 1972 through 1983.

TABLE 11-14

COMPARISON OF EXPORTS TO LEADING FOREIGN COUNTRIES (TOP 10)

COUNTRY	VALUE OF EXPORTS (MILLION $)		EXPORT GROWTH RATE 1979-82 (%)	PERCENT SHARE OF TOTAL 1982 EXPORTS
	1982	1979		
CANADA	317.0	256.9	23.4	12.6
JAPAN	270.3	233.6	15.7	10.8
U.K	263.9	233.5	13.0	10.5
NETHERLANDS	196.1	150.2	30.6	7.8
FRANCE	172.8	120.0	44.0	6.9
F.R. GERMANY	167.7	223.1	-24.8	6.7
AUSTRALIA	106.8	97.2	9.9	4.3
UNITED ARAB EMIRATES	102.1	42.8	135.5	4.1
ITALY	82.7	77.1	7.3	3.3
MEXICO	76.2	80.1	-4.9	3.0
TOTAL	2248.5	1514.5		70.0

1982 TOTAL EXPORTS (ALL COUNTRIES): $2.5 BILLION

SOURCE: MODERN PHOTOGRAPHY MAGAZINE: 1983-84 WOLFMAN REPORT ON THE PHOTOGRAPHIC INDUSTRY IN THE UNITED STATES

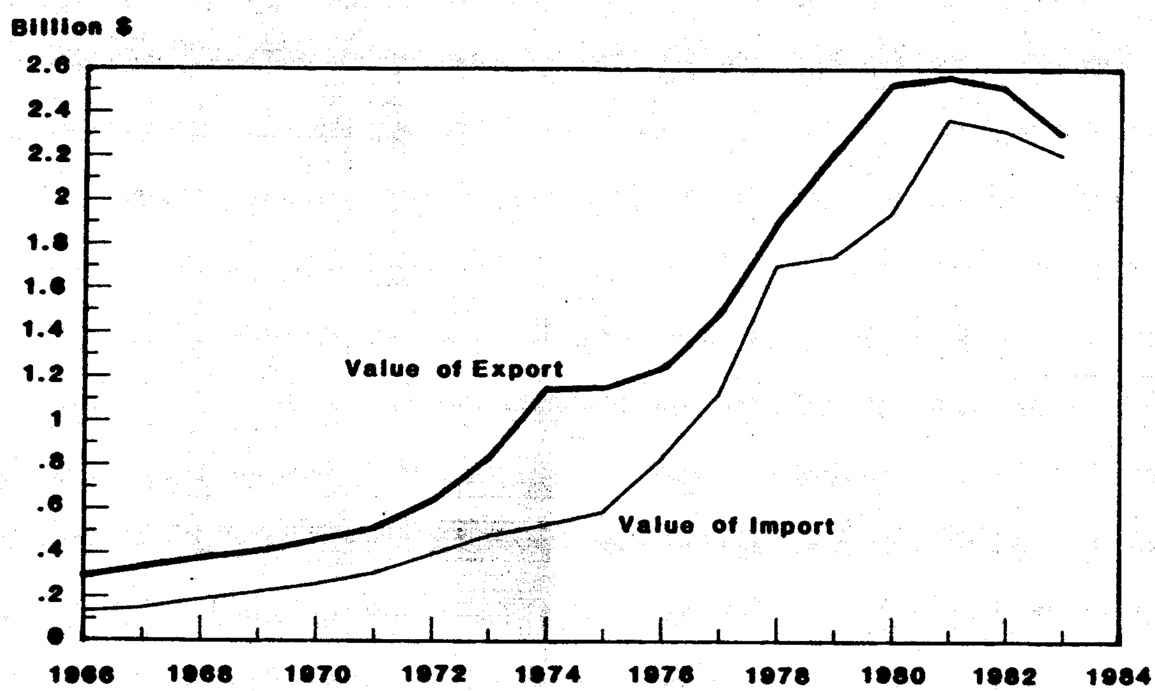
TABLE 11-15

COMPARISON OF IMPORTS FROM LEADING FOREIGN COUNTRIES (TOP 10)

COUNTRY	VALUE OF EXPORTS (MILLION $)		EXPORT GROWTH RATE 1979-82 (%)	PERCENT SHARE OF TOTAL 1982 EXPORTS
	1982	1978		
JAPAN	1642.4	1190.8	37.9	71.0
BELGIUM	136.5	61.7	121.1	5.9
CANADA	103.4	56.9	81.7	4.5
F.R. GERMANY	99.1	138.5	-28.4	4.3
TAIWAN	87.1	51.2	70.1	3.8
U.K.	58.0	39.3	47.6	2.5
HONG KONG	44.6	43.7	2.0	1.9
FRANCE	31.6	9.6	229.2	1.4
KOREAN REPUBLIC	24.2	18.8	28.7	1.0
ITALY	21.6	19.4	11.3	1.0
TOTAL	2248.6	1629.9		97.3

1982 TOTAL IMPORTS (ALL COUNTRIES): $2.3 BILLION

SOURCE: MODERN PHOTOGRAPHY MAGAZINE: 1983-84 WOLFMAN REPORT ON THE PHOTOGRAPHIC INDUSTRY IN THE UNITED STATES



Source: Department of Commerce and National Association of Photographic Manufacturers–1984 Wolfman Report on the U.S. Photographic Industry

Figure 11-6. Competitive Posture of the Photographic Equipment and Supplies Industry

Productivity in the Photographic Equipment and Supplies Industry

The figure in Table 11-11 shows that the U.S. productivity (output per employee hour) has been steadily increasing in this industry since 1967 at a rate of about 6% per year, with the exception of a slight downturn because of poor market conditions in 1980. At the same time, the Japanese productivity growth rate has been about four times higher. One cause of these high increases in productivity is the incorporation of inexpensive electronics in 35mm cameras, which eases manufacturing labor costs while bringing the product cost down.

Capital costs account for the largest proportion of production costs (48%). R&D amounts to around 15% of the value of industry shipments. Materials costs amount to 32% and are largely due to the precise requirements for product components, especially lenses and precision mechanisms. Labor costs amount to 19% of production costs and, therefore, do not have as large an effect on the product price as materials and capital costs.

Role of Technology in the Long-Term Strategic Outlook

Growth in the photographic equipment and supplies industry is highly cyclical. There is a surge in demand for new products immediately after an innovation is introduced to the market; but, in time, market demand for the product drops as a result of market saturation. The industry is therefore, classified as neither sunrise or sunset, but as cyclical.

The photographic equipment and supplies industry is a general indicator of socioeconomic conditions that reflect changes in unemployment, economic stability, family size, and consumer confidence. Cameras are generally considered a luxury item; thus, for the average consumer, camera and film sales reflect the amount of disposable income available.

As was previously mentioned, industry market performance is based in part on product innovation. The lens/shutter 35mm camera is a big seller and should continue to be in the near future, as technology improvements enable manufacturers to produce more highly automatic and cheaper products. New faster-speed films should result in more demand for film processing labs. The electronic imaging market should also grow, although silver halide imaging will still be the dominant method for the next generation of cameras; electronic imaging promises to be important to the long-term growth of this industry. Double digit growth of the video market will continue. Electronic enhancement will contribute to the growth of imaging labs and film scales providing sharper and clearer highlights on prints. The new 35mm camera will be a simplified SLR with some sort of telephoto or wide angle capability incorporated in it along with digital electronics that incorporate DX reading systems. DX is a black and silver digital code printed on the film that indicates the film type and speed for which the camera should set itself and establishes an automatic developing system (DX code developed in March of 1983 by KODAK Corp.). New product technologies and probable dates of significant dispersion throughout the industry are provided in Table 11-16.

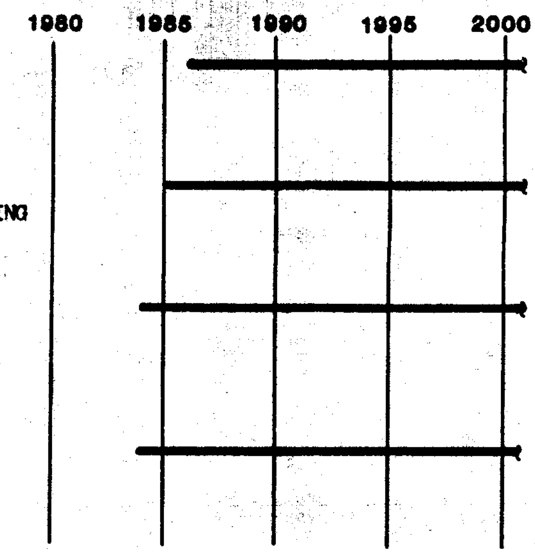
Summary

The photographic equipment and supplies manufacturing industry subdivision is characterized by a wide variety of products; including consumer market products such as hand-held cartridge and instant cameras, and business and industrial products such as film-processing equipment, photocopiers, microfilming equipment, cameras, and accesories for professional or industrial applications. U.S. producers will face increasing competitive pressure from Japan as it makes further advances in the U.S. domestic market. Given the nature of market risks and the cyclical nature of the photographic equipment and supplies market, it is especially difficult to predict what new technologies will appear on

TABLE 11-16

NEW PHOTOGRPAHIC TECHNOLOGIES

TECHNOLOGY	DESCRIPTION	PRINCIPAL IMPACT	APPROXIMATE ERA OF SIGNIFICANT DIFFUSION
ELECTRONIC STILL CAMERA	ELECTRONIC VIEWER WHERE PICTURES ARE DIGITALLY STORED ON MAGENTIC DISK.	EASIER TO USE CAMERA, PICTURE QUALITY DOES NOT DEGRADE.	
ELECTRONIC IMAGING (VCR, VHS, ETC)	VISUAL DATA IS DIGITIZED AND STORED ON DISK OR TAPE.	REDUCED CONSUMER PRICE FOR MOTION PICTURE TAKING AFTER INITIAL OUTLAY.	
COLOR FILM PRINTERS	HARDCOPY COLOR GRAPHICS: PRODUCE PRINTS OF PHOTO-GRAPHIC QUALITY FROM COLOR GRAPHICS TERMINAL OR VIDEO.	CAPABLE OF PRODUCING CONTINUOUS TONE IMAGES, BUT VERY EXPENSIVE.	
INK JET COLOR PRINTERS	HARDCOPY COLOR GRAPHICS: ELECTRONICALLY CONTROLLED JETS OF INK BASED ON DIG-ITAL IMAGE DATA.	QUIET, HIGH-SPEED PRINTING ON PLAIN PAPER.	



the horizons, or what their impact on the photographic equipment and supplies industry will be in the future.

B.11.4 CONCLUSIONS

Of the three subdivisions of the instruments and related products manufacturing subsector selected for in-depth analysis, both optical instruments and lenses, and surgical, medical and dental instruments are classified as sunrise industries, while photographic equipment and supplies is a cyclical industry. One leapfrog technology that may be applicable to the engineering and scientific personnel shortage in optical instrument manufacturing is accelerated learning. Leapfrog technologies affecting the surgical, medical, and dental instruments industry are custom multiproperty materials for biocompatible implants and prosthetics, new medical and biotechnology, and mobile energy storage systems for some prosthetics or artificial organs. New film and imaging technologies should have the greatest impact on the U.S. photographic equipment and supplies industry. Potential leapfrog technologies for this industry include custom multiproperty materials for an advanced image storage medium and novel mobile energy storage devices (such as long-life lithium batteries) to improve the performance of off-the-shelf imaging equipment.

B.12 "STONE, CLAY AND GLASS" (SIC 32)

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SOURCES: U.S. DOC/BOC:

Statistical Abstract of the U.S., 1982-3

Census of Manufactures, 1977

Annual Survey of Manufactures, 1981

U.S. DOC/BIE:

1984 U.S. Industrial Outlook

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B.12 "STONE, CLAY, AND GLASS" (SIC 32)

The stone, clay, and glass subsector, SIC 32, includes establishments engaged in manufacturing flat glass and other glass products, cement, structural clay products, pottery, concrete and gypsum products, ceramics, cut stone, and asbestos products from materials taken from the earth in the form of stone, clay, and sand. The subsector accounted for 3.1% of the manufacturing sector's value added contribution to GDP in 1980, ranking it twelfth within the 20 manufacturing subsectors. This subsector is characterized by:

- A high degree of fragmentation. Out of a total of approximately 18,000 establishments, 13,000 employed less than 20 persons (1977).

- A labor productivity of $21,979 per employee or $11.45 per employee hour (1980, 1972 $), ranking this subsector tenth among the nation's 20 manufacturing subsectors. A compound annual labor productivity growth rate average of 1.1%/year from, 1972 to 1980 ranks this subsector twelfth. The labor productivity for the comparable Japanese subsector was $12,897 per employee year or $6.72 per employee hour (1980, 1972 $), ranking this subsector eighth among Japan's 20 manufacturing subsectors. The compound annual labor productivity growth rate for the Japanese subsector averaged 5.8%/year from 1972 to 1980, ranking it third.

- A slightly higher than average capital investment base relative to other subsectors within the manufacturing sector. Capital investment amounted to $23,796 in total assets per worker, ranking fifth in terms of (depreciated) fixed assets (1980, 1972 $). New yearly capital expenditures were $2,784 per employee (1980, 1972 $), ranking sixth in the manufacturing sector.

Total capital productivity, measured as dollars of added value output per dollar of capital investment, was 0.47 (1981).

- A less than average R&D program. For the subsector as a whole, R&D expenditures amounted to $0.2 billion (1980, 1972 $), equivalent to 1.7% of the value added by the subsector in 1980, ranking this subsector twelfth among the 20 manufacturing subsectors.

Table 12-1 shows the major products of each subdivision of the stone, clay, and glass subsector, ranked in descending order in terms of their share of the subsector's contribution to GDP in 1980. Table 12-2 summarizes the principal economic measures of these subdivisions.

One subdivision--Concrete, Gypsum, and Plaster Products (SIC 327)--accounted for 30% of the subsector's output in 1980. Three other subdivisions--Glass Pressed or Blown (SIC 322), Pottery and Related Products (SIC 326), and Miscellaneous Nonmetallic Mineral Products (SIC 329)--all produce advanced ceramic products which are significant because of the technologies that their production requires. In assessing long-term technology needs, we have selected Concrete, Gypsum, and Plaster Products (SIC 327), and also the advanced ceramic products industry for further analysis.

B.12.1 CONCRETE, GYPSUM, AND PLASTER PRODUCTS (SIC 327)

Concrete Block and Brick (SIC 3271), Concrete Products (SIC 3272), and Ready-Mixed Concretes (SIC 3273) contributed 88% to the value of shipments of the concrete, gypsum and plaster products subdivision (SIC 327). Therefore, these three industries will be considered together in this analysis.

The concrete products industries include establishments that manufacture concrete building block and brick, concrete products,

TABLE 12-1

CLASSIFICATION OF THE MAJOR PRODUCTS OF THE STONE, CLAY, AND GLASS SUBSECTOR (SIC 32), AND RELATIVE CONTRIBUTION TO GDP IN 1980

SIC CODE	SUBDIVISION DESIGNATION AND TYPICAL PRODUCTS	% CONTRIBUTION
327	CONCRETE, GYPSUM, AND PLASTER PRODUCTS CONCRETE BLOCKS, AND BRICKS, DRY MIX CONCRETE, GRAVE MARKERS, SILOS, LIME, PLASTER OF PARIS, AND GYPSUM BOARD.	29.9
329	MISCELLANEOUS NONMETALLIC MINERAL PRODUCTS ABRASIVE BUFFS, BUFFING AND POLISHING WHEELS, HONES, STEEL WOOL, TRIPOLI, ASBESTOS, GASKETS, BARIUM, FLINT, LEAD, SHALE, TALC, GLASS WOOL, AND STUCCO.	23.0
322	GLASS PRESSED OR BLOWN JARS, JUGS, MILK BOTTLES, ASHTRAYS, CHRISTMAS TREE ORNAMENTS, OPTICAL GLASS, STEMWARE, AND GOBLETS.	18.2
324	CEMENT, HYDRAULIC PORTLAND, NATURAL, MASONRY, AND POZZOLAN CEMENTS.	8.8
323	PRODUCTS OF PURCHASED GLASS AQUARIUMS, DOORS, FURNITURE TOPS, AND LABORATORY GLASSWARE.	5.2
325	STRUCTURAL CLAY PRODUCTS CLAY TILE OF ALL TYPES, CLAY BLOCK, AND CLAY BRICK.	5.2
326	POTTERY AND RELATED PRODUCTS FLUSH TANKS, URINALS, SINKS, DISHES, BONE CHINA, COOKWARE, PORCELAIN KNOBS, SPARK PLUG PORCELAIN, FLOWER POTS, AND PORCELAIN TUBES.	5.0
321	FLAT GLASS CATHEDRAL GLASS, PICTURE GLASS, PLATE GLASS, SPECTACLE GLASS, SHEETGLASS, AND WINDOW GLASS.	3.5
328	CUT STONE AND STONE PRODUCTS ALTARS, BAPTISMAL FONTS, CURBING SLATE ROOFING, MONUMENTS, URNS, MARBLE STATUARY, AND MARBLE TABLE TOPS.	1.4
	ALL STONE, CLAY AND GLASS PRODUCTS	100.0

SOURCES: U.S. DOC/BOC: STATISTICAL ABSTRACT OF THE U.S., 1982-3
EOP/OMB: STANDARD INDUSTRIAL CLASSIFICATION MANUAL, 1972

TABLE 12-2

SUBDIVISIONS AND CHARACTERIZATION OF THE STONE, CLAY & GLASS SUBSECTOR (SIC 32) DURING 1980, IN 1972 DOLLARS

SUBDIVISION	PERCENTAGE CONTRIBUTION	NUMBER OF EMPLOYEES (1,000)	NUMBER OF ESTABLISHMENTS[a] TOTAL	LESS THAN 20 EMPLOYEES	100 OR MORE EMPLOYEES	GROSS VALUE OF FIXED ASSETS ($/EMPLOYEE)	NEW CAPITAL EXPENDITURES ($/EMPLOYEE)	LABOR PRODUCTIVITY ($/EMPLOYEE)
ALL STONE, CLAY & GLASS PRODUCTS (32)	100	613.3	17,744	12,543	1,236	23,796	2,784	21,979
FLAT GLASS (321)	5	17.3	62	30	24	54,573	8,786	27,288
GLASS PRESSED OR BLOWN (322)	19	110.2	508	259	198	22,936	2,349	22,269
PRODUCTS OF PURCHASED GLASS(323)	5	42.1	1,101	776	91	10,917	1,435	16,684
CEMENT, HYDRAULIC (324)	9	30.4	201	41	132	85,771	7,563	39,075
STRUCTURAL CLAY PRODUCTS (325)	6	43.5	711	240	128	19,239	1,702	15,999
POTTERY AND RELATED PRODUCTS (326)	4	43.4	934	693	105	8,818	877	15,624
CONCRETE, GYPSUM, & PLASTER PRODUCTS (327)	28	189.2	10,844	8,133	251	22,072	2,894	21,316
CUT STONE AND STONE PRODUCTS (328)	1	13.0	993	829	15	7,174	496	12,486
MISC. NONMETALLIC MINERAL PRODUCTS (329)	23	124.2	2,390	1,542	292	20,665	2,738	24,913

[a] 1977

SOURCE: U.S. DOC/BOC: CENSUS OF MANUFACTURES, 1977
ANNUAL SURVEY OF MANUFACTURES, 1981

and portland cement concrete in a ready-mix state. The historical and current posture of these industries is summarized in Tables 12-3 and 12-4, which portray their business and structural profiles, respectively. Table 12-3 shows that, expressed in constant 1972 dollars, shipments of these industries have decreased 12% in eleven years, from $6.9 billion in 1972 to $6.1 billion in 1983. Because of the recent economic recovery, the value of shipments is expected to rise to $6.5 billion in 1984, an increase of 7%. Employment declined by 17%, from a cyclical high of 185 million in 1979, to a low of 154 million in 1983. Labor productivity, i.e., output per employee hour, rose steadily until 1977; general decline has been apparent, however, from 1977 to 1984.

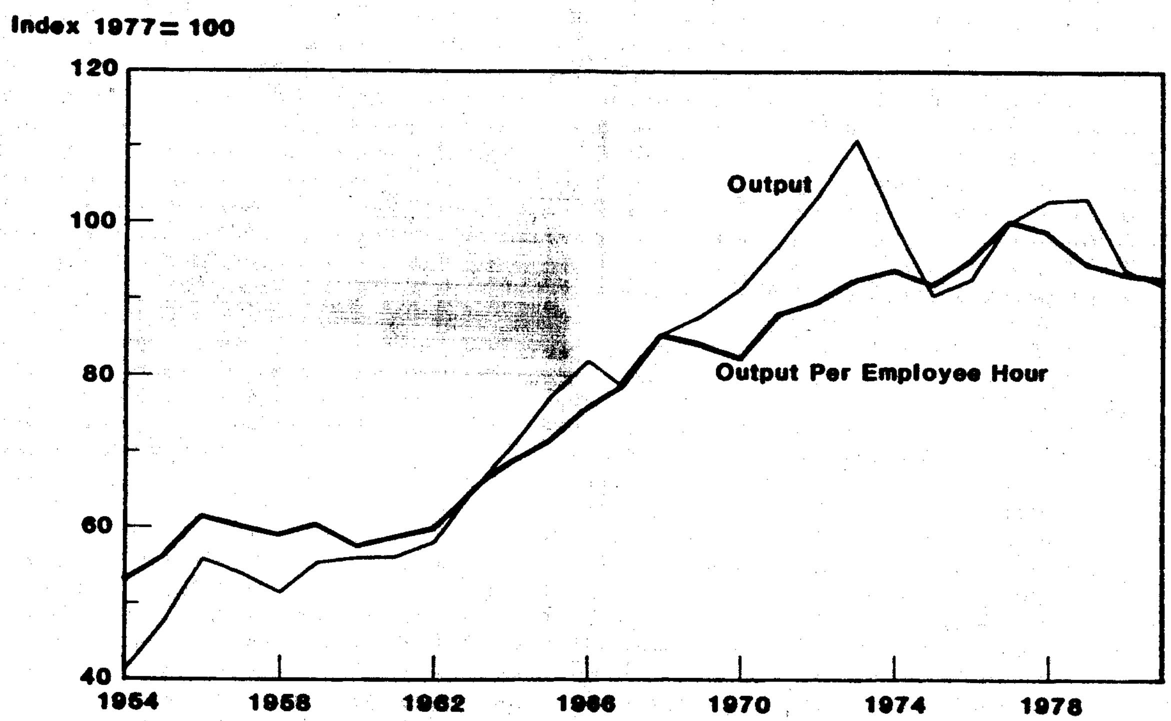
Table 12-4 shows that the concrete products industries' top seven firms accounted for $1.2 billion in sales during 1983. Of the 10,622 establishments, 76% employ less than 20 persons.

Table 12-5 shows that five dominant factors influence or constrain the concrete products industries. These industries are highly fragmented: Approximately 84% of the establishments are single owner firms with an average plant size of 16 persons. Therefore, very few internal R&D programs exist since their economic feasibility is limited by low capital expenditure capabilities and low economies-of-scale. Moreover, the diffusion of external technological innovations from the equipment manufacturing subsectors is slow because of the ownership diffusion among these industries. The industries' market demand closely follows that of the construction sector, and is, therefore, affected by several financial factors: Interest rates tend to fluctuate between wide extremes; companies often have to reserve capital for periods of low market demand because of the cyclical nature of the market, which limits the availability of investment capital for new technological advances.

TABLE 12-3

BUSINESS PROFILE OF THE CONCRETE PRODUCT INDUSTRIES
(SICs 3271, 3272, AND 3273)

SHIPMENTS (BILLION $)	1972	1977	1979	1981	1983	1984 EST.
CURRENT $	6.9	10.3	14.1	14.2	14.5	14.0
1972 $	6.9	6.8	7.3	5.8	6.1	6.5
EMPLOYMENT (THOUSANDS)	176	168	185	165	154	—
CAPITAL EXPENDITURES MILLION 1972$	390	388	490	341	—	—



Source: Published BLS Data

NET PROFIT MARGIN, 1983 % 8.7

SOURCES: U.S. DOC/BIE: 1984 U.S. INDUSTRIAL OUTLOOK
U.S. DOC/BOC: CENSUS OF MANUFACTURES, 1977

TABLE 12-4

STRUCTURAL PROFILE OF THE CONCRETE PRODUCTS INDUSTRIES (SICs 3271, 3272, 3273)

NUMBER OF ESTABLISHMENTS (CATEGORIZED BY NO. OF EMPLOYEES)		LEADING FIRMS (1983) NAME	SALES (MILLION 1972$)	NO. OF EMPLOYEES
SMALL (<20)	8,057	LONE STAR INDUSTRIES	435	8700
LARGE (>20)	2,567	GIFFORD-HILL	186	3600
		IDEAL BASIC	178	3415
TOTAL	10,624	TEXAS INDUSTRIES	152	3100
(8954 COMPANIES)		SOUTHDOWN	114	1100
		KAISER CEMEMT	102	1449

PRODUCTION COST DISTRIBUTION, 1977	MFG. LABOR	OTHER LABOR	MATERIALS	ENERGY	CAPITAL
	13%	7%	52%	2%	26%

R&D EXPENDITURES, (ALL SIC 32)	
CURRENT MILLION $, 1980	406

TRADE (MILLION 1972 $)	1972	1977	1979	1981	1983
VALUE OF EXPORTS	1.1	9.8	7.0	6.4	7.8
VALUE OF IMPORTS	7.9	4.0	10.2	8.9	8.5

SOURCES: U.S. DOC/BOC: CENSUS OF MANUFACTURES, 1977
1984 VALUE-LINE INVESTMENT SURVEY

TABLE 12-5

CONSTRAINT PROFILE OF THE
CONCRETE PRODUCTS INDUSTRIES

OWNERSHIP STRUCTURE	HIGHLY FRAGMENTED. AT LEAST 84% OF ESTABLISHMENTS ARE ONE PLANT FIRMS
INNOVATION	NEW TECHNOLOGY IS ADOPTED FROM OTHER INDUSTRIES (EQUIPMENT MANUFACTURING)
FISCAL/MONETARY POLICY	INDUSTRY IMPACTED BY INTEREST RATE FLUCTUATIONS
AVAILABILITY OF INVESTMENT CAPITAL	LOW COMPARED TO OTHER INDUSTRIES
MARKET DEMAND PATTERN	HIGHLY CYCLICAL, CLOSELY FOLLOWS THE CONSTRUCTION SECTOR

SOURCES: U.S. DOL/BLS

Competitive Issues Affecting the Concrete Products Industries

Table 12-4 summarizes export and import statistics for the concrete products industries. During the eleven year period from 1972 to 1983, exports rose over 600% from $1.1 million to $7.8 million (1972 $); imports rose by only 8% in the same period, from $7.9 million to $8.5 (1972 $). In 1983 the balance of trade showed only a $0.6 million (1972 $) deficit, while imports and exports were only 0.2% of total shipments, suggesting that foreign trade, most of which is with neighboring countries, is likely to remain small.

Productivity in the Concrete Products Industries

The data in Table 12-3, drawn from published BLS data, show that productivity for concrete products (excluding ready-mixed concrete) increased at an average annual rate of 3.1% from 1960 to 1977, as compared to 2.6% for all manufacturing. This increase in productivity can be partially attributed to the increased use of concrete products in the construction market because of the more widespread application of precast and prestressed concrete as opposed to structural steel and timber. Another reason for this rise in productivity was a 21% decline in smaller, less efficient concrete block establishments between 1967 and 1977. The recent drop in productivity--2.1% average annually from 1977 to 1981--derives from the impact of the recent recessions on the construction industry, which has reduced the market for concrete products.

As shown in Table 12-4, materials in the concrete products industry during 1977 totaled 52% of production costs, followed by capital expenditures at 26%, manufacturing labor at 13%, other labor at 7%, and energy costs at 2%.

Role of Technology in the Long-Term Strategic Outlook

The concrete products industries have been penetrating the construction sector (i.e., replacing traditional steel markets) through the use of improved reinforcing techniques in conjunction with other materials. The ability of concrete to be molded in virtually any shape or size enhances its appeal to architects. Energy conservation advantages can also be realized through the use of concrete: Passive solar applications are possible due to their heat absorption properties. The strength and resistance to earth conditions of concrete enhances its use for underground and earth-covered construction. These properties and the new commercial appeal of concrete indicate that the concrete products industry has not yet reached a saturation point with regards to the construction market. From 1984 to 1988, the industries constant dollar shipments are expected to rise 3%, exceeding the expected rate of growth of the construction sector.

New Technologies in the Concrete Products Industries

Table 12-6 summarizes the new technologies currently being developed and used by the concrete products industries. A synopsis of these technologies follows:

- Material handling technology is a major component of concrete products manufacturing. The highly mechanized systems use mobile platforms to move newly cast concrete to different operations inside the plant. Automatic cubers are used by the largest block plants in place of manual methods. The automatic cuber requires only periodic supervision and replaces four unskilled workers. The use of material handling technology can reduce the labor force required by 50%. Diffusion of these systems throughout the industry will be slow due to the number of small plants.

TABLE 12-6

NEW TECHNOLOGIES IN THE CONCRETE PRODUCTS INDUSTRIES (SICs 3271, 3272, 3273)

TECHNOLOGY	DESCRIPTION	PRINCIPAL IMPACT	APPROXIMATE ERA OF SIGNIFICANT DIFFUSION 1975 1980 1985 1990
IMPROVED MATERIAL HANDLING EQUIPMENT	PLATFORMS, TRANSFER CARS, OR CONVEYORS MOVE CONCRETE AND STACK IT AUTOMATICALLY. USED IN 25% OF PLANTS (1979), EXPECTED TO INCREASE IN LARGER PLANTS	REDUCES NEED FOR UNSKILLED LABOR	
IMPROVED CASTING METHODS	MORE EFFICIENT BLOCK MACHINES, SPECIALTY PRECASTING MACHINES, IMPROVED PRESTRESSED CONCRETE MANUFACTURING. USE LIMITED TO LARGER PLANTS (1979)	REDUCES LABOR REQUIREMENTS, MAKES STRONGER CONCRETE	
CURING METHODS: HOT CONCRETE, HOT OIL, AND AUTOCLAVE	PREHEATS CONCRETE FOR FASTER STRIPPING, REDUCES CURING TIME. HOT OIL USE WIDESPREAD, AUTOCLAVING IN 25% OF PLANTS, HOT CONCRETE USE LIMITED (1979)	SAVES UNIT LABOR COSTS	
AUTOMATIC BATCHERS	QUALITY OF CONCRETE IMPROVED THROUGH ELECTRONICALLY SELECTED, WEIGHED, AND PROPORTIONED AGGREGATES. USE IN 10% OF PLANTS, DIFFUSION TO SMALLER PLANTS UNLIKELY (1979)	OPERATOR NO LONGER CONTROLS PROCESS, ONLY MONITORS	

SOURCE: U.S. DOL/BLS

- Improved casting methods for blocks, specially designed precast shapes, concrete panels, and standard prestressed products (such as hollow-cored slabs) are being developed. Productivity will increase with the introduction of larger capacity block casting machines. The new machines can produce 1200 to 1600 standard 8-inch units/hour, while older machines developed in the 1960s can produce only 1000 units/hour. The larger block casting machines are currently used by only large block casting firms. Prestressed concrete (in which steel strands, tensioned by hydraulic jacks, are embedded in the concrete to increase tensile strength) is being improved to accelerate the casting process with hydraulic drives in some extruding machines. Diffusion has been very slow because of the small economies-of-scale and high equipment costs.

- Curing technologies will reduce labor in the concrete products industries by reducing inventories. Most firms currently cure concrete in the storage yard (because of the seasonal nature of the industry) which causes high inventory. Hot oil curing pumps hot oil under the length of the casting bed to heat and harden the concrete. Autoclave curing (for blocks and other small precast products) uses high pressure steam to cure the concrete and takes half the time of the old curing method. The hot concrete curing method preheats the concrete in the mixer, allowing it to cure in approximately half the time. Once again, diffusion will be slow due to industry fragmentation.

- Automatic batches improve quality control and allow for greater flexibility, although no actual labor savings are realized. These are used most often by manufacturers of ready-mixed concrete. Automatic batches electronically select, weigh, and apportion specific amounts of aggregates and cement for particular concretes. Computer integration of automatic batchers is also being implemented. Slow diffusion due to industry fragmentation is again the limiting factor.

Technological diffusion is generally limited throughout these industries by their small plant sizes, small local markets, and the cyclical demand for concrete. The extension of construction activity and, in particular, concrete manufacturing to a year-round function, and the greater standardization of building equipment, would improve conditions for technological diffusion.

Conclusion

Although the performance of the concrete products industries has historically been tied to that of the construction sector, the concrete products industries constant dollar shipments are expected to outgrow those of the construction sector in the next four years (1984-1988). This is due to the widespread application of precast and prestressed concrete in situations were structural steel and timber were used previously. This indicates that the concrete products industries have room for growth.

In summary:

- The ownership structure of these industries (84% of establishments are one plant firms) has impeded R&D activities due to the lack of capital.

- Foreign trade is not likely to be a factor in the industry due to the bulkiness of the product. Currently, most trade is with neighboring countries.

- There has been a recent drop in productivity (2.1% average annual decrease from 1977 to 1981) due to the depressed nature of the construction industry.

- Any new technologies in the concrete products industries will diffuse slowly due to the ownership structure, and the cyclical and seasonal nature of these industries.

B.12.2 ADVANCED CERAMIC PRODUCTS INDUSTRY

The advanced ceramic (AC) products industry, like many new emerging industries, is not classified within the Standard Industrial Classification System, whose codes have not been revised since 1972. Rather, this industry combines elements from several subdivisions, including Glass Pressed or Blown (SIC 322), Pottery and Related Products (SIC 326), and Miscellaneous Nonmetallic Mineral Products (SIC 329). This industry includes establishments which manufacture AC products valued for their hardness, strength, and their thermal and electrical properties, all of which are used in high-performance engines, machines, and electronic components.

The current and estimated future business profile of the advanced ceramic industry is summarized in Table 12-7. Expressed in constant 1972 dollars, industry shipments are forecasted by DOC to increase nearly ten fold in 20 years, from $335 million in 1980 to $3.26 billion in 2000. This growth can be broken down into industry components. Figure 12-1 illustrates U.S. AC industry shipments (by end use) for 1980 (1972 $); these include integrated circuit packaging (38% of the total), capacitors (39%), resistors (13%), cutting tools (7%), and wear parts (3%).

Integrated circuit packaging, the fitting of semiconductor integrated circuits into larger boards, provides a suitable operating environment within a computer for a working microchip. Materials used in capacitors, by shipments in 1982 (Figure 12-2), shows that ceramic use accounted for 78% of shipments. This segment of the industry is expected to grow 877% in the next 20 years, from $123 million in 1980 to $1.2 billion (1972 $) by the year 2000. Capacitors, which store electric energy control

TABLE 12-7

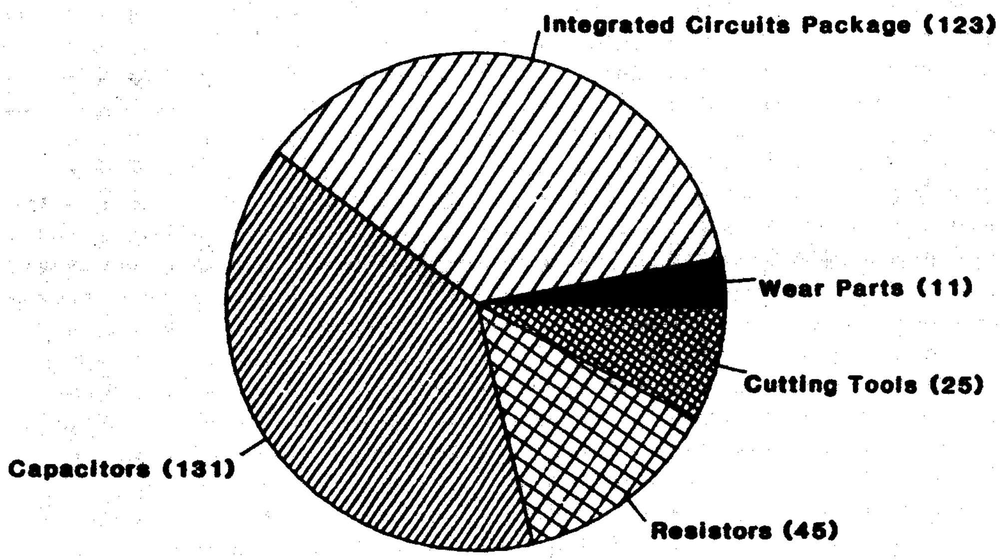
BUSINESS PROFILE OF THE
ADVANCED CERAMICS INDUSTRY

VALUE OF CERAMICS CONTENT IN U.S. INDUSTRY

SHIPMENTS (MILLIONS 1972 $)	1980	1985	1990	1995	2000
ALL INDUSTRY	335	728	1396	2200	3265
ELECTRONIC COMPONENTS	299	610	1051	1466	1953
• INTEGRATED CIRCUIT PACKAGING	123	331	583	886	1202
• CAPACITORS	131	195	336	407	504
• OTHER ELECTRONIC USES	45	84	132	173	247
ENGINEERING PRODUCTS	36	118	345	734	1312
• CUTTING TOOLS	25	81	213	336	538
• WEAR PARTS	11	25	101	210	303
• HEAT ENGINE PARTS	0	12	31	188	471

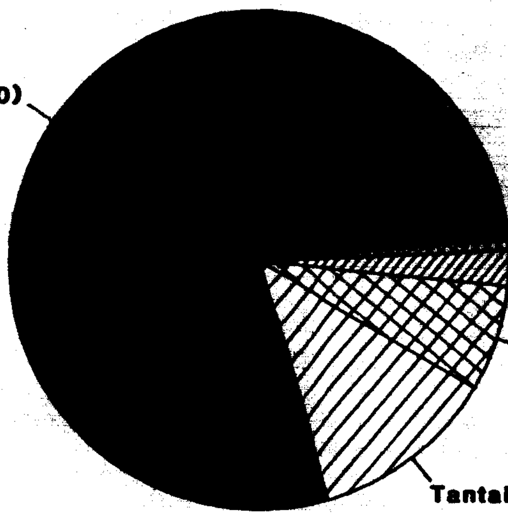
FEDERAL GOVERNMENT FUNDED R&D FOR ENGINEERING CERAMIC TECHNOLOGY, FY 1982	AMOUNT (MILLION 1972 $)
DEPARTMENT OF ENERGY	8.1
• VEHICLE AND ENGINE R&D	5.2
• INDUSTRIAL PROGRAM	0.2
• ENERGY SYSTEMS RESEARCH	0.2
• OTHER	2.5
NASA	0.8
NATIONAL SCIENCE FOUNDATION	0.6
DEPARTMENT OF DEFENSE	3.3
TOTAL	12.8

SOURCES: U.S. DOC/INDUSTRY ANALYSIS DIVISION
U.S. DOE/OFFICE OF VEHICLE & ENGINE R&D



Source: U.S. DOC/Industry Analysis Division,
Office of Chemical and Allied Products.

Figure 12-1. U.S. Advanced Ceramic Shipments by End Use



Source: U.S. DOC/Bureau of Industrial Economics.

Figure 12-2. U.S. Capacitor Shipments by Materials Used for 1982

the flow of alternating current, and block the flow of direct current, are a major segment of the AC industry. A growth rate of 285% in twenty years is expected, from $131 million in 1980 to $504 million (1972 $) in the year 2000. Other electronic uses, such as magnetic components, resistors, and sensors are expected to grow from $45 million in 1980 to $247 million by 2000, a 449% increase.

Advanced ceramics are being used extensively in cutting tools, due to their hardness. The majority of these ceramic cutting tools are used by the aircraft engine industry for machining specialized superalloys and by the automotive industry for cast iron machining. From 1980 to the year 2000, the shipments of AC cutting tools are expected to rise from $25 million to $538 million, (1972 $) a 2052% increase. Their use in wear parts, ball bearings, pump parts, mechanical seals, nozzles, etc., is currently limited, but is expected to rise. In the next 20 years, a 2655% jump in overall use could be realized, from $11 million to $303 million (1972 $). Heat engine parts are not being used commercially at the present time; however, by the year 2000 their use should reach the $471 million (1972 $) mark.

These figures generally suggest that the AC industry will grow rapidly and diffuse into many different industries. Table 12-8 shows major firms in the U.S. currently involved in advanced ceramic production and research, by type of product.

Competitive Issues Affecting the Advanced Ceramics Industry

Figures 12-3 and 12-4 show the percent of international patents issued, from 1970 to 1982, in ceramic compositions and ceramic coatings products, respectively. Figure 12-3 shows that U.S. international patents on ceramic compositions decreased from 78% in 1970 to 50% in 1982; among foreign competitors, Japan's international patents increased from 6% in 1970 to 24% in 1982. Figure 12-4 shows that U.S. international patents on ceramic

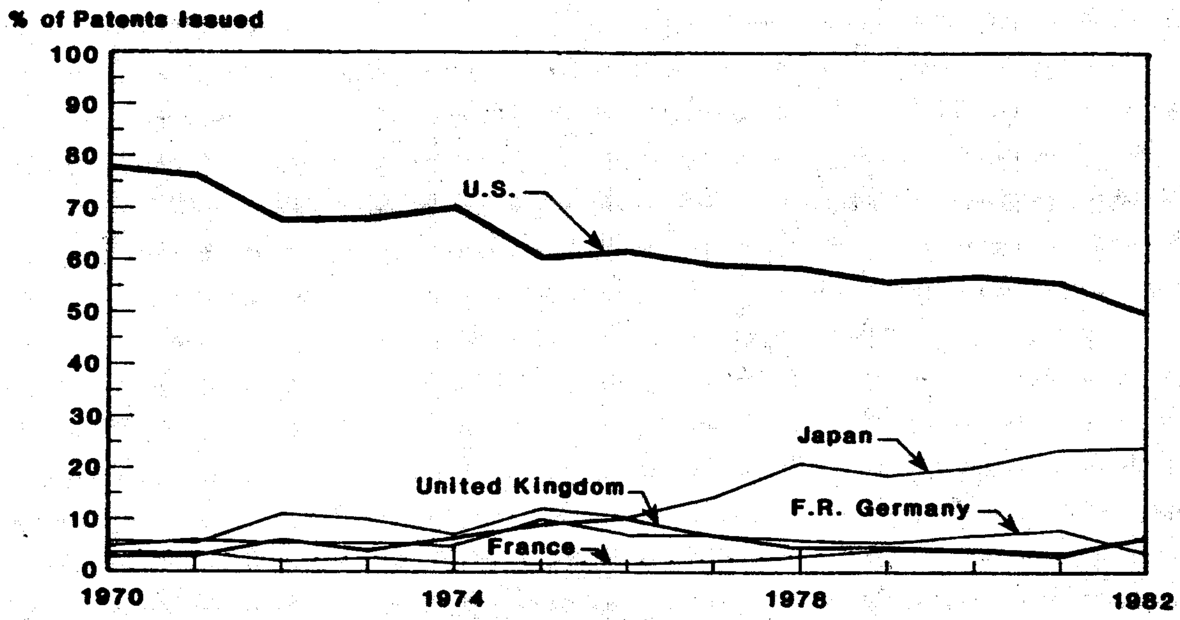
TABLE 12-8

U.S. FIRMS CURRENTLY INVOLVED IN ADVANCED CERAMIC PRODUCTION AND RESEARCH, BY PRODUCT TYPE

CERAMIC POWDER PRODUCERS	INTEGRATED CIRCUIT PACKAGING (IC)	CAPACITORS	OTHER ADVANCED CERAMICS	CERAMIC POWDERS, ICs CAPACITORS AND OTHER ADVANCED CERAMICS COMBINED
CORNING GLASS	MONSANTO	AVX	MONSANTO	IBM
COORS PORCELAIN	BRUSH WELLMAN	KEMET	GTE SYLVANIA	HONEYWELL
NORTON	INTERAMICS	SPRAGUE	PLESSEY, INC.	G.E.
CARBOUNDUM	CERAMIC SYSTEMS	CENTRALAB	CERAMICS INTL.	TEXAS INSTRUMENTS
ALCOA		STE		MOTOROLA
TAM CERAMIC		CORNING GLASS		RCA
AMERICAN LAVA		VITRAMON		
		UNITRODE		

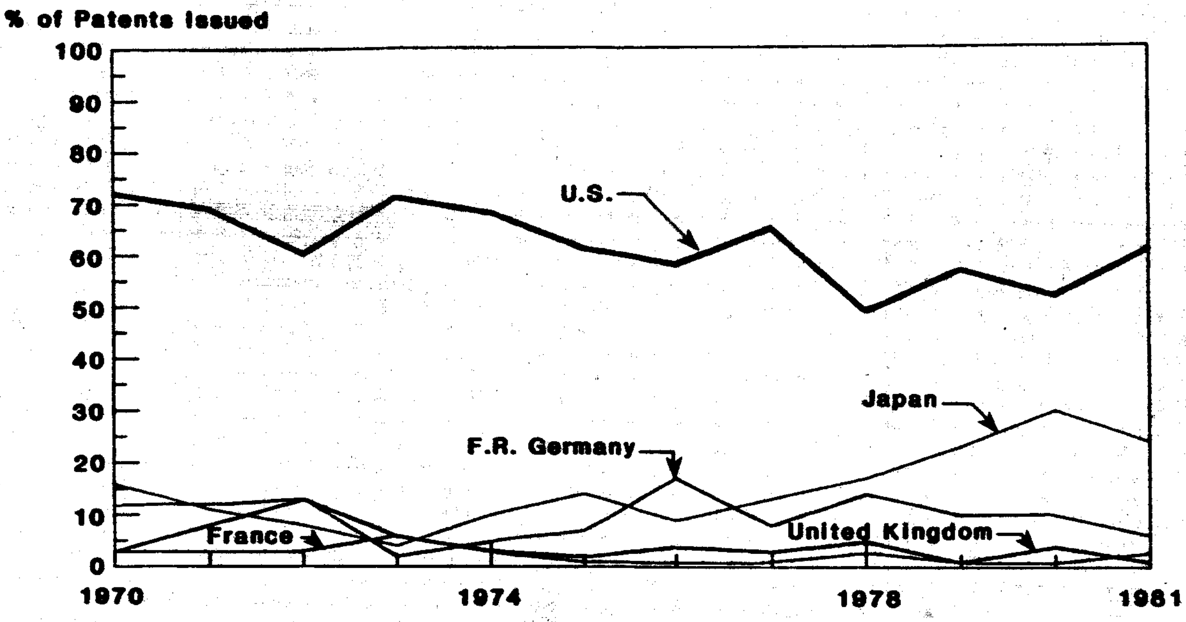
CUTTING TOOLS	WEAR PARTS	ENGINE DESIGN	CERAMIC MATERIALS AND PARTS
KENNAMETAL, INC.	CARBORUNDUM	FORD MOTOR	CARBORUNDUM
BABCOCK AND WILCOX	GENERAL ELECTRIC	CATERPILLAR TRACTOR	DUPONT
COORS PORCELAIN	NORTON	GARRETT	CELANESE
TRW	COORS PORCELAIN	CUMMINS	DOW-CORNING
ADAMS CARBIDE	ART INC.	GENERAL MOTORS	NORTON
CARBOLOGY SYSTEMS DEPT.	ESK	WESTINGHOUSE	CORNING GLASS
GTE WALMET		INTERNT'L HARVESTOR	COORS PORCELAIN
TALIDE METAL CARBIDES		G.E.	CERAMTECH INC.
VALENITE		PRATT AND WHITNEY	GTE SYLVANIA
TELEDINE FIRST STERLING		HAGUE INTERNT'L	G.E.
			KAMAN SCIENCES
			UNITED TECHNOLOGIES
			AIRESEARCH CASTING
			CERADYNE, INC.

SOURCE: U.S. DOC/INDUSTRY ANALYSIS DIVISION



Source: U.S. DOC, Patent Technology Assessment Forecast, Custom Report by Patent and Trademark Office, 9/13/83.

Figure 12-3. International Patent Activity-Ceramic Compositions



Source: U.S. DOC, Patent Technology Assessment Forecast,
Custom Report by Patent and Trademark Office, 9/13/83.

Figure 12-4. International Patent Activity-Ceramic Coating (Glass or Ceramic Based)

coatings fell from 72% in 1970 to 61% in 1981, whereas Japan's rose from 4% in 1970 to 24% in 1981. Because of the significant increases in international patents issued to Japan, its AC industry will be further analyzed.

The U.S. Department of Commerce delineates a future pattern of Japanese domination of this industry as follows: "If things continue as they are now, our assessment is that the United States will fall behind Japan in the field of advanced engineering ceramics. Our reasons . . . are as follows:

- Japanese domination of the electric components portion of the advanced ceramics industry;
- Japanese domination of the supply of advanced ceramic powders;
- The greater and more organized R&D effort currently being undertaken in Japan;
- Initial performance/cost characteristics of Japanese demonstration products;
- Japanese reputation for investing in long-term product-market development and accepting short-term losses;
- The Japanese record in developing and implementing superior commercial manufacturing processes and process technologies."

Japan has claimed much of the world market, as shown in Table 12-9. The integrated circuit packaging market is now controlled by the Japanese, who are estimated to produce 80 to 90% of total world AC production. Kyocera (a Japanese firm located in San Diego) and IBM dominate AC integrated circuit packaging within the U.S., with Kyocera claiming 70% of the shipments.

TABLE 12-9

PRODUCTION OF ADVANCED CERAMIC PRODUCT LINES, 1980

PRODUCT LINE (1972 $)	JAPAN PRODUCTION (MILLION $)	% OF WORLD MARKET	WORLD PRODUCTION (MILLION $)
CERAMIC POWDERS	$ 72.9	52	140.1
INTEGRATED CIRCUIT PACKAGING	302.7	61	493.2
CAPACITORS	182.2	43	420.3
PIEZOELECTRICS	165.3	91	182.2
THERMISTOR/VARISTORS	70.1	63	112.1
FERRITES	213.0	79	269.0
GAS/HUMIDITY SENSORS	2.8	11	25.2
TRANSLUCENT CERAMICS	11.2	44	25.2
CUTTING TOOLS	70.1	12	574.5
STRUCTURAL CERAMICS	67.3	48	140.1
TOTAL	1157.6	49	2381.9

SOURCE: GEORGE B. KENNEDY AND H. KENT BOWEN, "HIGH TECH CERAMICS IN JAPAN - CURRENT AND FUTURE MARKETS" AMERICAN CERAMIC SOCIETY BULLETIN, MAY 1983

Production figures on IBM are not available because of the company's vertical integration. The world market for AC packaging, expected to experience the most growth in the electronic AC capacitor and resistor markets, is currently evenly split by the U.S. and Japan worldwide. Japan has gained its advantage in AC electronic components by using a superior, large-scale manufacturing process which results in lower production costs. Currently, IBM is the only U.S. firm that is competitive in the development of AC electronic components.

Trends in world market shares in AC engineering products (cutting tools, wear parts, heat engine parts) have not been established yet because of the small amounts of commercial production that have occurred. Japan is currently the dominant world supplier of pure ceramic powders from which these AC products are made. When large-scale commercial production of AC engineering products begins (projected to be before 1995), competition will be based on quality and price. The quality of AC engineering products is judged by thermal properties, hardness, corrosion resistance, and predictability of catastrophic failure. These products give no indication of failure through deformation, but instead disintegrate into smaller pieces, as opposed to conventional materials, which show signs of wear.

Role of Technology in the Long-Term Strategic Outlook

The AC products industry is definitely in the sunrise stage of development, as shown by its predicted growth in Table 12-7. New proposed technologies for the industry can be separated into advanced ceramic electronic components and advanced ceramic engineering products. The theory behind these technologies is discussed in Section E.1. Applications of these new technologies to various industries are discussed here and shown in Table 12-10.

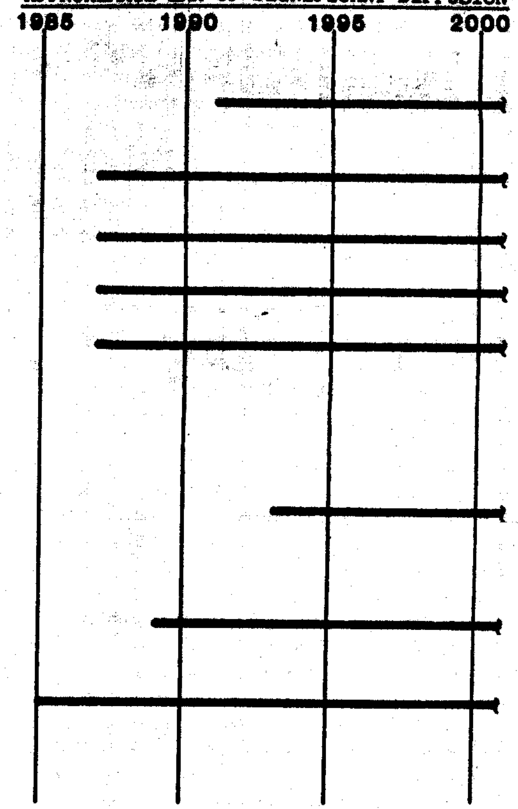
The electronic components and applications of advanced ceramic technology are as follows:

TABLE 12-10

APPLICATIONS OF ADVANCED CERAMIC TECHNOLOGY

APPLICATION	DESCRIPTION	PRINCIPAL IMPACT
ELECTRONIC APPLICATIONS		
• CAPACITORS	ADVANCED CERAMIC CAPACITORS MORE EFFICIENT CAPACITORS	INEXPENSIVE, SMALLER
• INTEGRATED CIRCUIT PACKAGING	FITTING IC CHIPS INTO CIRCUIT BOARDS	HIGHER PERFORMANCE AND RELIABILITY
• RESISTORS	ADVANCED CERAMIC THERMISTOR	IMPROVED CONTROL
• SENSORS	GAS AND TEMPERATURE SENSORS	BETTER CONTROL
• MAGNETIC COMPONENTS	PERMANENT MAGNETS, MEMORY UNITS, RADIO CIRCUIT ELEMENTS	SMALLER SIZE, LOWER COST
ENGINEERING PRODUCTS		
• HEAT ENGINE APPLICATIONS	IMPROVED PISTON ENGINES, CERAMIC ADIABATIC DIESEL ENGINE, CERAMIC GAS TURBINE ENGINE	INCREASED FUEL EFFICIENCY, MORE POWERFUL ENGINES
• CUTTING TOOLS	ADVANCED CERAMIC CUTTING EDGES EASIER USE OF ROBOTIC CUTTERS	HIGHER CUTTING SPEEDS
• WEAR PARTS	BEARINGS, SEALS, AND NOZZLES TECHNIQUES IN SOME INDUSTRIES	IMPROVE MANUFACTURING

APPROXIMATE ERA OF SIGNIFICANT DIFFUSION



SOURCE: U.S. DOC/IAD

- **Capacitors**--Multilayer ceramic capacitors are valued for their low capacitance levels, high dielectric constant, high resistivity, and low leakage. They are used in consumer electronic products, computers, telecommunications equipment, and scientific instruments. Cost, size, and speed of these capacitors will affect their future market. Major cost reduction can be achieved through the use of base metals (nickel, lead, and tin) in production as opposed to the noble metals (gold, platinum, palladium, and silver) currently being used. Noble metals currently account for 35% of the total cost of a multilayer ceramic capacitor. Reduction in capacitor size and an increase in capacitance value will increase the market share. Volumetric efficiency can be increased by increasing the dielectric constant, reducing the number of dielectric layers, or decreasing the thickness of dielectric layers. Use of new dielectric materials (lead, iron, tungsten, and lead iron niobate), better controlled processing parameters, increased automation, and improvements in ceramic powder purity will have to be used in order to meet this need. The speed of advanced ceramic capacitors (to be compatible with higher speeds of future integrated circuits) can be increased through the use of ceramic chip capacitors. These chip capacitors need to be standarized by size in order to gain wide market acceptance.

- **Integrated Circuit Packaging**--Advanced ceramic integrated circuit (IC) packaging is used to fit the semiconductor chip into larger circuit boards. A suitable operating environment within the computer or electronic device is produced by advanced ceramic IC packaging. Currently, the military is the primary user of ceramic IC packaging. The most promising ceramic IC packaging being developed is based on multilayer ceramic sub-

strates, consisting of layers of ceramic insulators alternating with conductor circuitry to form high-density wiring packages. As with ceramic capacitors, increased market share applications will depend on cost, size,and speed.

- **Resistors**--The use of ceramic thermistors should find increasing use as heat sensors in automobiles, to supply exhaust temperature data important to fuel efficiency, and in microwave and gas ovens.

- **Sensors**--The use of advanced ceramics in sensors is due to the semiconducting properties of ceramics, which allow them to transmit current only under certain conditions.

- **Magnetic Components**--AC materials with magnetic properties are used in permanent magnets, memory units, and circuit elements. They are derived from iron oxides combined with one or more metals (nickel, manganese, and zinc).

Advanced ceramic technology includes the following engineering applications:

- **Heat Engine Applications**--Advanced ceramics in heat engines will probably be used first in standard vehicular piston engines as components in cylinders, pistons, and turbochargers because major changes in production lines and engine technology will not be required for these applications. The major reason for using ceramic engines is their increased system performance, improved wear capability and lower weight. Critical flaws will also be easier to control. Turbocharger rotors are the most significant near-term item of an advanced ceramic component substitution. Ceramic

rotors are made from sintered silicon carbide. Research in ceramic turbocharger rotors is being conducted with private money, as opposed to most other heat engine applications which are government funded. Near-term ceramics substitution of other piston engine components include pistons and piston rings, cylinder liners and heads, valve lifters, and combustion chambers. Total ceramic piston engines are unlikely because they do not offer substantial gains in fuel economy or power production to warrant mass production. However, there are new vehicular engine designs which do offer significant gains in fuel economy and power production. These include the adiabatic diesel engine, which is made possible through the use of advanced ceramics. As compared to the conventional diesel engine, energy loss can be reduced by 50%, fuel consumption by 25%, and power can be increased significantly in the adiabatic diesel engine. These engines use thermal energy, normally lost to the coolant and exhaust systems, to make power through the use of turbomachinery. Use of a ceramic combustion chamber, (operating at high temperatures and reducing heat loss) with a turbocompound system, recovers the heat energy of the exhaust gases and transfers them to the crankshaft. Improved fuel economy and greater engine reliability is the result. The U.S. Army Tank Automotive Research and Development Command has been doing research in this area since 1976. Use in military and civilian heavy-duty trucks will come before use in automobiles.

Gas turbine engine use in vehicles became feasible in the 1960s with the development of advanced ceramic materials. Previously, the expense of the superalloys and their inability to withstand the high-operating temperatures prevented this development. AC gas tur-

bine engines alleviate the problem of expensive alloys, provide high temperature capabilities, and reduce wear on engine parts. Advantages of the turbine engine include improved fuel economy, lower engine weight, reduced maintenance, improved performance, and less pollutants. Currently the Department of Defense Advanced Research Projects Agency (DARPA) funds four R&D programs dealing with AC turbine engines. Stationary AC gas turbine engines are also being developed. The use of these engines in aircraft will be the last to be implemented, because of the high-performance needed and high-risk involved.

- **Cutting Tools**--Recent advances in AC materials and processing have made them competitive with high-speed steel and carbide cutting tools. Hardness, chemical stability, and heat resistance are all characteristics which give AC cutting tools an advantage. Ceramic materials are superior for cutting highly abrasive materials due to their resistance to wear, and are more effective for cutting at high speeds due to their resistance to heat. Resistance to thermal shock is one area where AC cutting tools are lacking because of their brittleness. Cutting tool use is currently very limited as compared to the potential market. Technological advances in the area of brittleness and thermal shock resistance (as compared to carbide machine tools) are needed before cutting tools can claim a substantial market piece. Silicon nitrate-based materials are considered to have a much greater potential than aluminum oxide ceramics, which have been available for 30 years. Alloying ceramic material with zirconia or titanium is being tried to improve fracture toughness. Unmanned machining (robotics) favors AC cutting tools because of the stiffness and long-life of the ceramic inserts.

- **Wear Part Applications**--Ball and roller bearings for high-performance applications made of AC materials (silicon nitride in particular) are now finding limited use in industrial machinery, for corrosive oil, gas, and chemical processing, and are being researched for use in automobile and aircraft engines. Improved processing methods have allowed densification of silicon carbide and silicon nitride, which has increased their tolerance to point or stress loading. The light weight, heat resistance, and wear resistance of ceramic bearings are major advantages over conventional (tungsten/steel) bearings. Their light weight makes the centrifugal load lower, thereby improving fatigue life and high-speed performance. Conventional tool steel (the highest temperature resistant material now in use) softens excessively after being exposed to high temperatures for long periods of time. Higher temperature resistant bearings (i.e., advanced ceramic bearings) will be necessary for future high-speed industrial machinery. Advanced ceramic pump seals are used in sand slurries, chemical processing, and oil and gas recovery. Currently they are the most widely used AC product in the wear parts category. The same properties that make AC products useful in other applications (hardness, low friction, high resistance to corrosion, high temperature capability) make them useful in pump seals. Temperature characteristics of advanced ceramics have made them perfect for this application, because of the need to dissipate heat at the surface of the seal. Stability of shape when heated quickly (dimensional stability) is also a critical feature of advanced ceramics. Sandblast nozzles are now being made of advanced ceramics due to the need for nozzles with high wear capabilities and abrasion resistance.

Table 12-11 lists the strategic materials that advanced ceramics could replace. Clearly, advanced ceramics will be a key to the future technological development of many industries.

Conclusion

The advanced ceramic industry is clearly experiencing rapid growth. Advances in AC technology are continuing in the areas of ceramic powder production, integrated circuit packaging, capacitors, cutting tools, wear parts, engine design, and other advanced ceramics products.

Industry shipment of AC products are expected to increase nearly ten fold in the next 20 years. AC products could replace the following strategic materials: tungsten, cobalt, nickel, chromium, molybdenum, manganese, titanium, platinum and palladium, columbium, and tantalum.

Currently, the U.S. and Japan are virtually equal with regards to technology in the field. If current conditions remain unchanged, U.S. will fall behind Japan in AC technology. According to the U.S. Department of Commerce, there are two categories of technology push and market pull. The technology push option involves:

- Federal R&D expenditures increased for advanced engineering ceramics. The money should be directed at solving the AC problem of catastrophic failure and at finding cost-effective manufacturing techniques.

- Provide an improved technology transfer function of AC technology from military and space applications to the private sector.

- Increase private R&D on AC technology through federal incentives such as tax incentives, matching funds, and low-interest loans.

TABLE 12-11

POSSIBLE ADVANCED CERAMICS SUBSTITUTION FOR STRATEGIC MATERIALS

MATERIAL	SYMBOL	APPLICATION WHERE CERAMICS MAY REPLACE THE MATERIAL	TECHNOLOGICAL BARRIERS FOR CERAMICS
TUNGSTEN	W	WEAR PARTS (LINERS, PADS, NOZZLES, BEARINGS, GATES, SLIDES, VALVES, SEALS).	DEMONSTRATION, SCALE UP, COST
COBALT	Co	DIESEL COMBUSTION PARTS	DEMONSTRATION, COST
		TURBOCHARGER ROTORS	N/A
		HEAT RECOVERY SYSTEMS	N/A
NICKEL	Ni	DIESEL COMBUSTION PARTS	DEMONSTRATION, PROPERTIES; MAINTENANCE OF CURRENT CREEP AND OXIDATION LEVELS, COST
		TURBOCHARGER ROTORS	N/A
		HEAT RECOVERY SYSTEMS	FABRICATION AND PERFORMANCE INNOVATIONS, DEMONSTRATION, COST
		CHEMICAL WARE (ANTI-CORROSION PIPING, VALVES, SEALS, ETC., GASIFIER COMPONENTS, COATINGS)	N/A
CHROMIUM	Cr	HEAT ENGINES	DEMONSTRATION, PROPERTIES, COST
		CHEMICAL WARE	N/A
		HEAT EXCHANGERS	FABRICATION, PERFORMANCE, DEMONSTRATION, COST
MOLYBDENUM	Mo	HEAT RECOVERY SYSTEMS	N/A
MANGANESE	Mn	HEAT ENGINES	DEMONSTRATION, PROPERTIES, COST
TITANIUM	Ti	WEAR PARTS	DEMONSTRATION, SCALE-UP, COST
		CUTTING TOOLS AND ABRASIVES	ACHIEVE HARDNESS, NEW COMPOSITES
		HEAT APPLICATIONS	N/A
PLATINUM AND PALLADIUM	Pt,Pd	CHEMICAL WARE	N/A
BERYLLIUM	Be	STRUCTURAL MEMBERS (FIBER REINFORCED SPARS; TILES; CASTINGS)	INNOVATION IN COMPOSITES, ORGANO-CERAMICS TECHNOLOGY DEVELOPMENT
COLUMBIUM (NIOBIUM)	Nb	HIGH-TEMPERATURE APPLICATION	FABRICATION, PERFORMANCE, DEMONSTRATION
TANTALUM	Ta	HIGH-TEMPERATURE APPLICATION	COSTS, HARDNESS POTENTIAL
		WEAR PARTS	N/A

N/A - NOT AVAILABLE.

SOURCE: L.R. JOHNSON, ET AL., "A STRUCTURAL CERAMIC RESEARCH PROGRAM: A PRELIMINARY ECONOMIC ANALYSIS," ARGONNE NATIONAL LABORATORY, MARCH 1983

- Improve the capacity of the U.S. to transfer foreign scientific advances in the AC field. This is one particular area where Japan is much better equipped.

- Stimulate universities and colleges to train advanced ceramics engineers by offering them federal funds for their programs.

The market pull option includes:

- To purchase federal items on the basis of their content of advanced ceramic products. This could include military items, automobiles, and office computing equipment.

- The Bureau of Standards must set reliability standards in AC products to insure quality.

- To provide AC producers with liability insurance due to the problem of AC catastrophic failure.

The primary need for advanced ceramic research, however, is in the areas of solving the catastrophic failure problem and in finding a cost-effective method of production.

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SOURCES: U.S. DOC/BOC:

Statistical Abstract of the U.S. 1982-83

Census of Manufacturers, 1977

Annual Survey of Manufacturers, 1981

EOP/DMB:

Standard Industrial Classification Manual, 1972

U.S. DOC/BIE:

Industrial Outlook, 1984

U.S. DOL/BLS:

Value-Line Investment Survey, 1984

Moody's Handbook, 1984

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B.13 "RUBBER AND MISCELLANEOUS PLASTICS PRODUCTS" (SIC 30)

The rubber and miscellaneous plastics products subsector, SIC 30, whose value added accounted for 2.9% of the manufacturing sector's contribution to GDP in 1980, comprises the 14th largest manufacturing industry (in this study, the apparel and other textile products subsector, SIC 23, the 13th largest manufacturing industry will not be covered). The subsector is characterized by:

- A high degree of fragmentation. Out of a total of approximately 18,000 establishments, 13,000 employ less than 20 persons (1977).

- A low labor productivity of $17,988 per employee or $9.37 per employee hour (1980, 1972 $), ranking this subsector fourteenth among the nation's 20 manufacturing subsectors. A compound annual labor productivity growth rate average of -0.6%/year from 1972 to 1980 ranks this subsector last. The labor productivity for the comparable Japanese subsector was $11,508 per employee year or $5.99 per employee hour (1980, 1972 $), ranking this subsector eleventh among Japan's 20 manufacturing subsectors. The compound annual labor productivity growth rate for the Japanese subsector averaged 4.4%/year from 1972 to 1980, ranking this subsector sixteenth.

- An average capital investment base relative to other subsectors within the manufacturing sector. Capital investment amounted to $15,962 in total assets per worker, ranking eighth in terms of (depreciated) fixed assets (1980, 1972 $). New yearly capital expenditures were $1,648 per employee (1980, 1972 $), ranking eleventh in the manufacturing sector. Total capital productivity, measured as dollars of added value output per dollar investment, was 0.82 (1981).

- An average R&D program. For the subsector as a whole, R&D expenditures amounted to $0.4 billion (1980, 1972 $), ranking this subsector eighth among the 20 manufacturing subsectors. R&D expenditures were equivalent to 2.9% of the value added by the subsector in 1980.

Table 13-1 shows the major products of each subdivision of the rubber and miscellaneous plastics products industry, with their share of the subsector's contribution to GDP in 1980 ranked in descending order. Table 13-2 summarizes the principal economic measures of these subdivisions.

One subdivision--miscellaneous plastics products (SIC 307 or 3079) which consists of manufactured plastic products of all types with the exception of plastic footwear and plastic hose/belting--accounted for 64% of the subsector's output in 1980. Because this subdivision considerably dominates the other subdivisions within this industry, it has been selected for analysis in order to assess long term technology needs.

B.13.1 MISCELLANEOUS PLASTICS PRODUCTS (SIC 307)

The total plastics industry produced $54 billion in shipments in 1983. The miscellaneous plastics products subdivision accounted for $37 billion of shipments or 68%; the remaining 32%, classified as plastics materials and resins (SIC 2821), constitutes captive production or the self-manufacture of plastic products to be consumed within other major industry groups. Examples of the latter are the automotive industry, food packaging materials, and toy manufacturers. Miscellaneous plastics products are associated with all other plastic products industries (with the exception of plastic footwear and plastic hose/belting).

TABLE 13-1

CLASSIFICATION OF MAJOR PRODUCTS OF THE RUBBER AND MISCELLANEOUS PLASTICS PRODUCTS INDUSTRY (SIC 30) AND CONTRIBUTION TO SUBSECTOR IN 1980

SIC CODE	SUBDIVISION DESIGNATION AND TYPICAL PRODUCTS	% CONTRIBUTION
307	**MISCELLANEOUS PLASTICS PRODUCTS** PLASTIC PRODUCTS OF ALL TYPES EXCEPT PLASTIC FOOTWEAR AND PLASTIC HOSE/BELTING	64.4
301	**TIRES AND INNER TUBES** RUBBER INNER TUBES, TIRES, AND TIRE REPAIR MATERIALS	18.0
306	**OTHER FABRICATED RUBBER PRODUCTS** INDUSTRIAL AND MECHANICAL RUBBER GOODS, RUBBERIZED FABRICS AND VULCANIZED RUBBER CLOTHING	12.0
304	**RUBBER AND PLASTICS HOSE AND BELTING** AUTOMOBILE, GARDEN, VACUUM AND OTHER RUBBER AND PLASTIC HOSES AND BELTS	4.1
302	**RUBBER AND PLASTICS FOOTWEAR** RUBBER AND PLASTIC BOOTS, SHOES, AND OTHER FOOTWEAR	1.4
303	**RECLAIMED RUBBER** RECLAIMED RUBBER PRODUCTS OF ALL TYPES	0.1
30	ALL RUBBER AND PLASTIC PRODUCTS	100.0

SOURCES: U.S. DOC/BOC: STATISTICAL ABSTRACT OF THE U.S. 1982-3
EOP/OMB: STANDARD INDUSTRIAL CLASSIFICATION MANUAL, 1972

TABLE 13-2

SUBDIVISIONS AND CHARACTERIZATION OF RUBBER AND MISCELLANEOUS PLASTICS INDUSTRY (SIC 30) DURING 1980, IN 1972 DOLLARS

SUBDIVISION	PERCENTAGE CONTRIBUTION	NUMBER OF EMPLOYEES (1,000)	NUMBER OF ESTABLISHMENTS[a]			GROSS VALUE OF FIXED ASSETS/ ($/EMPLOYEE)	NEW CAPITAL EXPENDITURES ($/EMPLOYEE)	LABOR PRODUCTIVITY ($/EMPLOYEE)
			TOTAL	LESS THAN 20 EMPLOYEES	100 OR MORE EMPLOYEES			
ALL RUBBER & MISC. PLASTICS (30)	100	703.2	11,943	6,649	1,554	15,967	1,648	17,988
TIRES AND INNER TUBES (301)	18.0	87.2	200	74	94	28,122	2,126	26,196
RUBBER, PLASTICS FOOTWEAR (302)	1.4	18.0	84	34	34	4,132	389	9,581
RECLAIMED RUBBER (303)	0.1	0.6	21	12	3	38,112	747	22,979
RUBBER AND PLASTICS HOSE, BELTING (304)	4.1	32.4	146	43	63	22,286	2,064	15,856
FABRICATED RUBBER PRODUCTS (306)	12.0	94.9	1,280	659	237	11,354	950	16,006
MISC. PLASTICS PRODUCTS (307)	64.4	470.1	10,212	5,827	1,123	14,626	1,722	17,328

[a] 1977

SOURCE: U.S. DOB/BOC: CENSUS OF MANUFACTURES, 1977
U.S. DOC/BOC: ANNUAL SURVEY OF MANUFACTURES, 1981

Business and structural profiles of the miscellaneous and plastic products subdivision are presented in Tables 13-3 and 13-4, respectively. Table 13-3 shows that industry shipments expressed in constant 1972 dollars, have increased 55% in eleven years, from $10.7 billion in 1972 to $16.6 billion in 1983. Employment rose steadily up to 1979, after which it stabilized at a slightly lower level. Labor productivity, i.e., output per employee hour, rose from 1972 to 1977, and has stabilized at that level.

Table 13-4 shows that the miscellaneous plastics products industry is highly fragmented; 75% of its establishments employ less than 20 persons. A typical manufacturer in this industry earned a net income of 3% after taxes in 1981 on sales of about $5 million. The typical plastics fabricator is a small, independent business with a potential for modular operations and incremental expansion. Its finished product is dominated primarily by the cost of input materials (49%), and secondarily by manufacturing and other labor (21%) costs. In 1979 and 1983, the value of exports in this industry was nearly twice the size of imports.

The dominant constraint in the miscellaneous plastics products industry is cost. Because plastic is a petrochemical-based product, the cost of plastic is dependent on the cost of oil.

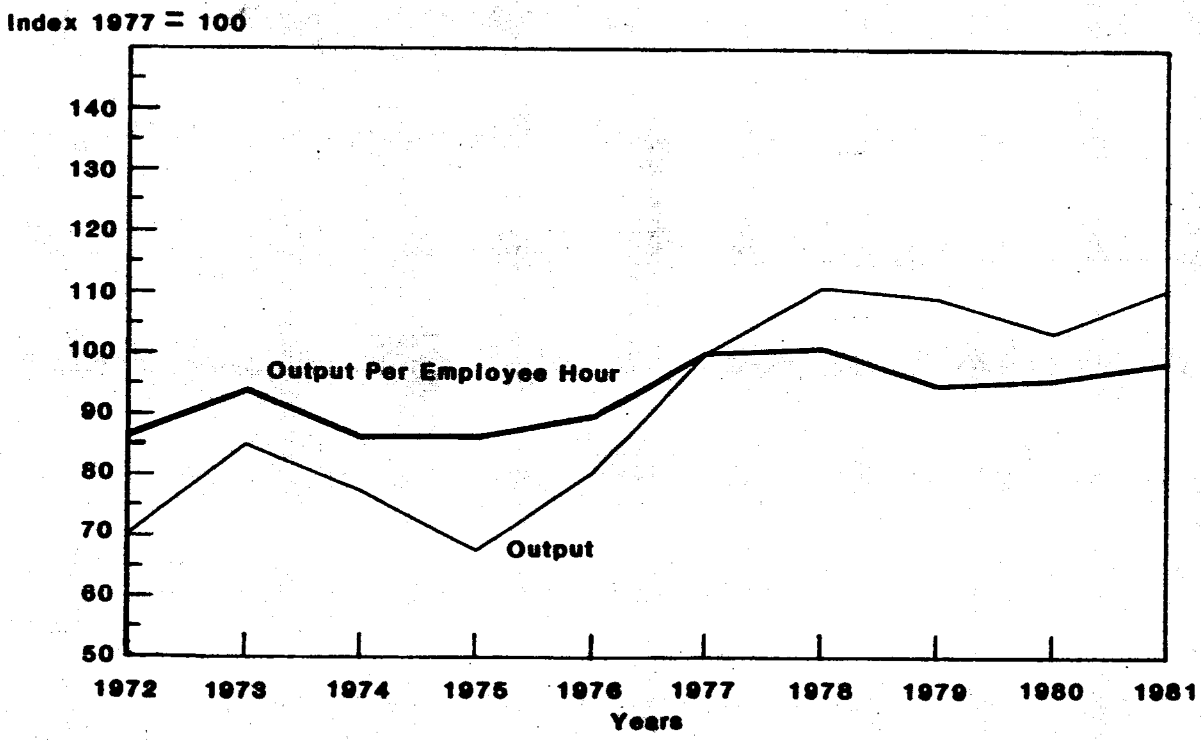
Key Growth Influences in the Miscellaneous Plastic Products Industry

The use of fabricated plastic parts has undergone a significant change in focus over the last five years. Whereas the early growth of the industry was driven by the low cost substitution of plastic parts for natural materials, advances in polymer and processing technologies in the 1980s have resulted in the production of plastic parts with superior performance to natural

TABLE 13-3

BUSINESS PROFILE OF THE MISCELLANEOUS PLASTICS PRODUCTS INDUSTRY (SIC 307)

SHIPMENTS (BILLION $)	1972	1977	1979	1981	1983	1984 EST
CURRENT $	10.7	23.7	29.1	34.1	37.0	—
1972 $	10.7	14.6	15.6	15.7	16.6	17.9
TOTAL EMPLOYMENT (THOUSANDS)	346.9	453.7	487.7	469.5	452.2	465.0



Source: BLS Data

PLANT CAPACITY UTILIZATION, 1982 %	64.0
PRETAX PROFIT, 1981, %	4.2
RETURN ON EQUITY, 1983, %	4.7
VALUE OF PLANT, 1976, CURRENT $, BILLION	7.3

	1977	1981
NEW CAPITAL EXPENDITURES, CURRENT $, BILLION	1.2	1.6

SOURCES: U.S. DOC/BIE: 1984 U.S. INDUSTRIAL OUTLOOK
U.S. DOC/BOC: CENSUS OF MANUFACTURES, 1977
U.S. DOL/BLS
VALUE-LINE INVESTMENT SURVEY, 1984

TABLE 13-4

STRUCTURAL PROFILE OF THE
MISCELLANEOUS PLASTICS PRODUCTS INDUSTRY (SIC 307)

ESTABLISHMENTS (1977)

(CATEGORIZED BY NO. OF EMPLOYEES)

SMALL (< 20)	5,827
INTERMEDIATE (20 - 1000)	4,368
LARGE (> 1000)	17
TOTAL (8,824 COMPANIES)	10,212

REPRESENTATIVE FIRMS (1983)

NAME	TOTAL REVENUES (MILLION $)
RUBBERMAID, INC.	436.4
WEST CO., INC	190.4
SEALED AIR CORP.	124.5

	MFG. LABOR	OTHER LABOR	MATERIALS	ENERGY	CAPITAL
PRODUCTION COST DISTRIBUTION, 1977	14%	7%	49%	2%	28%

R&D EXPENDITURES

CURRENT $, MILLION, 1981	500

INTERNATIONAL TRADE	1972	1979	1983
VALUE OF EXPORTS, CURRENT $, BILLION	0.38	1.5	1.9
VALUE OF IMPORTS, CURRENT $, BILLION	0.25	0.8	1.0

SOURCES: U.S. DOC/BIE: 1984 U.S. INDUSTRIAL OUTLOOK
U.S. DOC/BOC: CENSUS OF MANUFACTURES, 1977
MOODY'S HANDBOOK, 1984

materials (e.g., ceramics, metals, and wood). At the same time, the average cost of high performance resins has continued to drop through the use of alloying or blending with lower-cost commodity thermoplastics. The result, in many cases, is a lower-cost, higher-performing plastic part.

A second major growth influence in the plastics products industry is the key role that plastics fabrication plays in the rapidly-growing electronics industry, in areas as diverse as printed circuit boards and business machine housings.

Technology Trends In The Miscellaneous Plastics Products Industry

Most technological advances which impact the plastic products industry are developed outside the industry. For example, the packaging industry has been a leading proponent of the so-called "plastic can", a product being developed to replace the metal can in many food applications. The actual development process has involved packaging companies, plastic resin companies, equipment manufacturers and, of course, fabricators. In point of fact, the packaging company, equipment company, and resin manufacturer work out the details and the fabricator will "take orders" for producing the final product. Another second source of technical development is derived directly from equipment manufacturers, a group that has a vested interest in developing new and different equipment in order to obsolete "old" machines and maintain industry shipments.

This outside influence is typical of the plastic products industry, in which smaller fabrication companies do not have the budget or interest to take on any but the most elementary research and development projects. They prefer to leave this work to the larger resin and/or food packaging companies. In all probability, any significant product or process developments will come from these integrated companies.

Plastic fabrication processes which show the highest level of future activity include:

- Resin transfer molding
- Twin screw extrusion and compounding
- Reaction injection molding (RIM)
- Sheet molding compound (SMC) and injection molding of bulk molding compound
- Pultrusion
- Thermoforming
- Sheet and film co-extrusion and lamination, and
- Injection blow-molding and co-extrusion blow-molding

All of these technologies are being pursued today and many are already part of viable commercial operations. Future development efforts are likely to be focused on such areas as cold stampable polymers, high-strength structural composites, super-high temperature polymer processing, flame-retardant plastic products, biodegradable plastic parts, and so on. However, it is unlikely that any of these development efforts will be supported by the fabrication industry itself. These projects will be undertaken by resin manufacturers, end users, or outside third parties.

Long-Term Technological Assessment of the Miscellaneous Plastics Products Industry

Over the next five to 15 years, the miscellaneous plastics products industry should experience a solid, but cyclical growth rate as the redefined role of substitution and the growth of the electronics industry drive plastic products demand. In-house fabrication together with selected custom fabricators will support most of these technology developments. However, these developments will be more likely driven by the end user rather than the fabrication process itself. In the longer term, as the needs of end users become more sophisticated and product and

process technology becomes more proprietary, the role of the independent fabricator in areas outside of commodity applications could be decreased.

The technological challenge in this industry will continue to be the development and fabrication of synthetic materials with superior performance and light weight--so called high performance structural composites. Superior performance will depend on two factors: 1) the material used, a function of the up-stream industries; and 2) the method of "putting materials together." Current research in these areas is driven by the automotive and air transportation industries. This research will incorporate developments from all segments of the chemical, polymer and fabricated products industries and will have wide-ranging applications. For example, in the long term, synthetic material could go a long way towards replacing conventional building materials.

Generally, the long-term technological challenge will be to derive the same performance from synthetic materials--cubic inch for cubic inch--that is currently possible from conventional materials such as steel and wood. Pound for pound, synthetics are already superior to natural materials in many end uses, and, the inventory of useable synthetic materials is quite large: 50 unique polymers, a dozen or so fibers, and an almost unlimited number of fillers and additives. It is most likely, therefore, that future breakthroughs in the development of structural synthetic materials will derive from selecting the right materials among a multitude of choices and fabricating them in such a way as to achieve a unique performance.

Assuming that both the materials and a structure are available, key technologies will also depend upon the designing of machines to perform a particular task. An example which received considerable publicity was the design and fabrication of a structural skeleton for a space station. Work is currently being performed on an epoxy-impregnated carbon-fiber ribbon, which can

be fed into a fabricating machine and converted into a structural "beam". This lightweight, yet strong material, and the process associated with its conversion to a useful product, could greatly reduce the cost of building in space.

In addition, new technologies need to be developed in the adhesives industry. As synthetic building materials emerge, new ways must be developed to hold the pieces together--quite likely mechanical fasteners will give way to chemical fasteners or adhesives.

Many of these technology issues have already surfaced in the aerospace and automotive industry as engineers have sought improved fuel economy through weight reduction. For example, the relatively simple task of aligning automotive body parts for welding became nearly impossible when the industry started using plastic with pre-drilled holes--the parts would never line up exactly with the holes. A potential solution to this problem is to use adhesives. However, there is clearly a long way to go before we can efficiently produce these products with synthetic materials.

In the future, it will become more difficult to distinguish between rubber and plastic products. Alloys and blends of elastomers and plastic resins are common today and will increase over time. Plastic resins provide stiffness for rubber products and elastomers provide impact resistance and flexibility for plastic products. Both are made from synthetic resins which are derived from many of the same basic molecules. Thus, the final part of this challenge will be to look beyond conventional industry boundaries in search of all kinds of materials which can be combined with rubber and plastic to create new structural composites.

Conclusion

The miscellaneous plastics products industry is one of the fastest growing industries in the U.S., although at present it is the smallest (in-terms of value-added contribution to GDP) industry reviewed in this report. In the future, the industry is expected to continue to grow faster than the U.S. economy in general as plastics are combined with textiles, fiberglass, rubber, and carbon fibers to produce composites to replace currently-used conventional materials. The new composite materials will be found in a wide range of products ranging from aircraft and automobiles to buildings.

The miscellaneous plastics products industry has an average R&D program but augments developments that arise with research advances developed by other industries.

The needs of the industry can be categorized into two areas:

- Development of synthetic materials to replace wood and metal as structural building materials, and to replace or be blended more with rubber. Currently, this development is dependent upon research results from the chemical, polymer, and fabricated products industries.

- New technologies are needed to develop chemical adhesives to replace currently used mechanical fasteners.

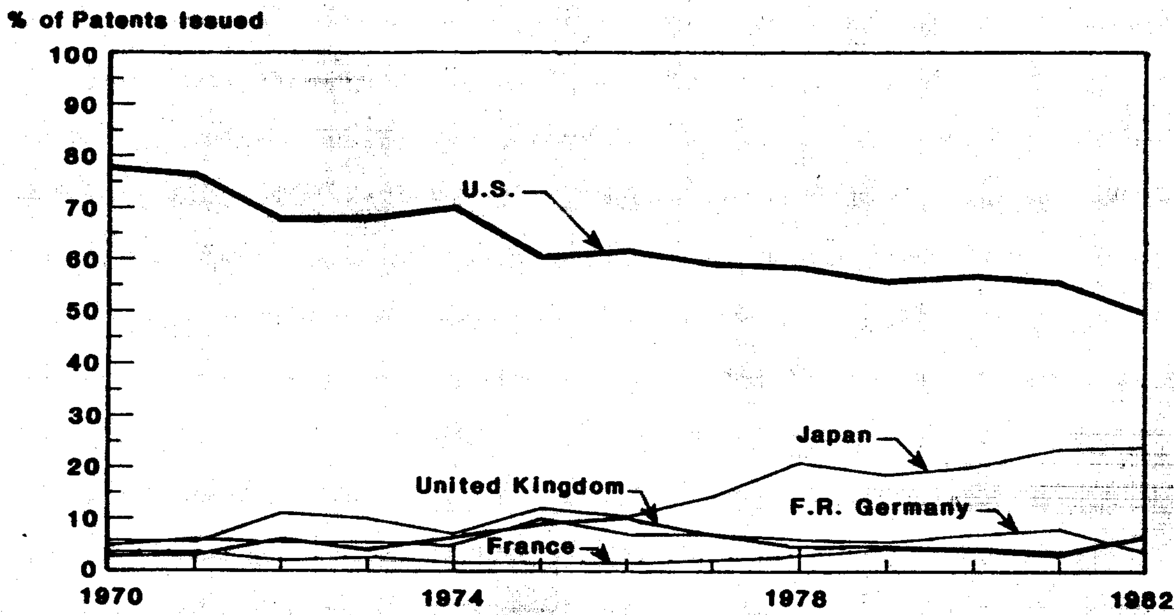
TABLE 12-8

U.S. FIRMS CURRENTLY INVOLVED IN ADVANCED CERAMIC PRODUCTION AND RESEARCH, BY PRODUCT TYPE

CERAMIC POWDER PRODUCERS	INTEGRATED CIRCUIT PACKAGING (IC)	CAPACITORS	OTHER ADVANCED CERAMICS	CERAMIC POWDERS, ICs CAPACITORS AND OTHER ADVANCED CERAMICS COMBINED
CORNING GLASS	MONSANTO	AVX	MONSANTO	IBM
COORS PORCELAIN	BRUSH WELLMAN	KEMET	GTE SYLVANIA	HONEYWELL
NORTON	INTERAMICS	SPRAGUE	PLESSEY, INC.	G.E.
CARBOUNDUM	CERAMIC SYSTEMS	CENTRALAB	CERAMICS INTL.	TEXAS INSTRUMENTS
ALCOA		STE		MOTOROLA
TAM CERAMIC		CORNING GLASS		RCA
AMERICAN LAVA		VITRAMON		
		UNITRODE		

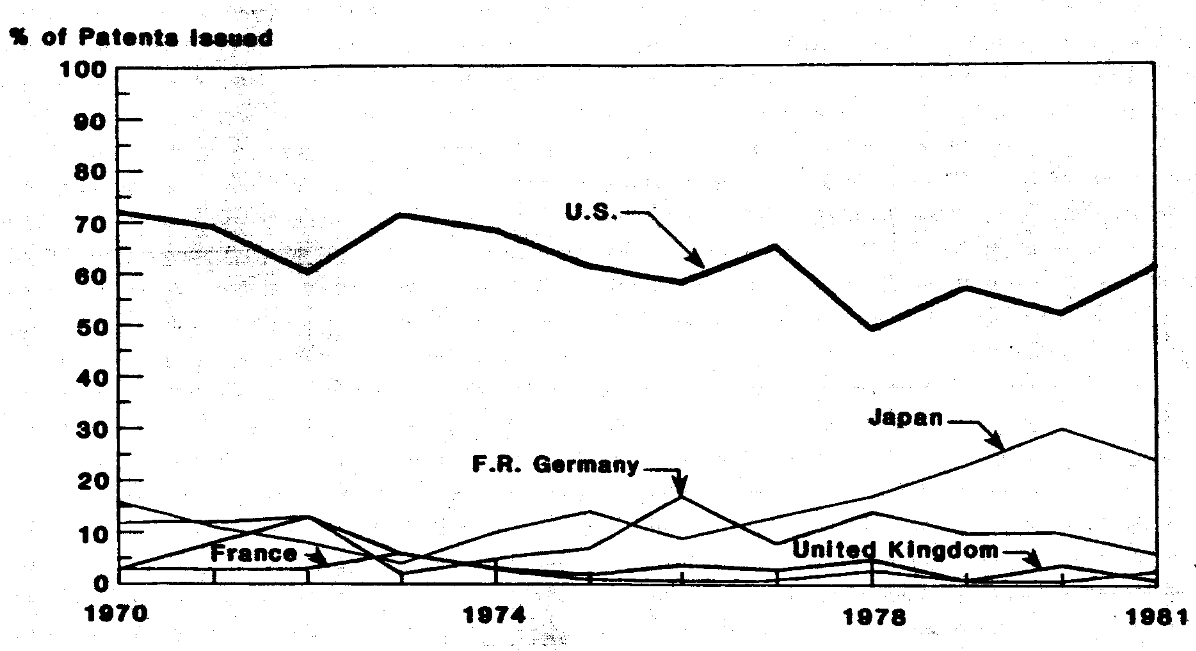
CUTTING TOOLS	WEAR PARTS	ENGINE DESIGN	CERAMIC MATERIALS AND PARTS
KENNAMETAL, INC.	CARBORUNDUM	FORD MOTOR	CARBORUNDUM
BABCOCK AND WILCOX	GENERAL ELECTRIC	CATERPILLAR TRACTOR	DUPONT
COORS PORCELAIN	NORTON	GARRETT	CELANESE
TRW	COORS PORCELAIN	CUMMINS	DOW-CORNING
ADAMS CARBIDE	ART INC.	GENERAL MOTORS	NORTON
CARBOLOGY SYSTEMS DEPT.	ESK	WESTINGHOUSE	CORNING GLASS
GTE WALMET		INTERNT'L HARVESTOR	COORS PORCELAIN
TALIDE METAL CARBIDES		G.E.	CERAMTECH INC.
VALENITE		PRATT AND WHITNEY	GTE SYLVANIA
TELEDINE FIRST STERLING		HAGUE INTERNT'L	G.E.
			KAMAN SCIENCES
			UNITED TECHNOLOGIES
			AIRESEARCH CASTING
			CERADYNE, INC.

SOURCE: U.S. DOC/INDUSTRY ANALYSIS DIVISION



Source: U.S. DOC, Patent Technology Assessment Forecast, Custom Report by Patent and Trademark Office, 9/13/83.

Figure 12-3. International Patent Activity-Ceramic Compositions



Source: U.S. DOC, Patent Technology Assessment Forecast, Custom Report by Patent and Trademark Office, 9/13/83.

Figure 12-4. International Patent Activity-Ceramic Coating (Glass or Ceramic Based)

coatings fell from 72% in 1970 to 61% in 1981, whereas Japan's rose from 4% in 1970 to 24% in 1981. Because of the significant increases in international patents issued to Japan, its AC industry will be further analyzed.

The U.S. Department of Commerce delineates a future pattern of Japanese domination of this industry as follows: "If things continue as they are now, our assessment is that the United States will fall behind Japan in the field of advanced engineering ceramics. Our reasons . . . are as follows:

- Japanese domination of the electric components portion of the advanced ceramics industry;

- Japanese domination of the supply of advanced ceramic powders;

- The greater and more organized R&D effort currently being undertaken in Japan;

- Initial performance/cost characteristics of Japanese demonstration products;

- Japanese reputation for investing in long-term product-market development and accepting short-term losses;

- The Japanese record in developing and implementing superior commercial manufacturing processes and process technologies."

Japan has claimed much of the world market, as shown in Table 12-9. The integrated circuit packaging market is now controlled by the Japanese, who are estimated to produce 80 to 90% of total world AC production. Kyocera (a Japanese firm located in San Diego) and IBM dominate AC integrated circuit packaging within the U.S., with Kyocera claiming 70% of the shipments.

TABLE 12-9

PRODUCTION OF ADVANCED CERAMIC PRODUCT LINES, 1980

PRODUCT LINE (1972 $)	JAPAN PRODUCTION (MILLION $)	% OF WORLD MARKET	WORLD PRODUCTION (MILLION $)
CERAMIC POWDERS	$ 72.9	52	140.1
INTEGRATED CIRCUIT PACKAGING	302.7	61	493.2
CAPACITORS	182.2	43	420.3
PIEZOELECTRICS	165.3	91	182.2
THERMISTOR/VARISTORS	70.1	63	112.1
FERRITES	213.0	79	269.0
GAS/HUMIDITY SENSORS	2.8	11	25.2
TRANSLUCENT CERAMICS	11.2	44	25.2
CUTTING TOOLS	70.1	12	574.5
STRUCTURAL CERAMICS	67.3	48	140.1
TOTAL	1157.6	49	2381.9

SOURCE: GEORGE B. KENNEDY AND H. KENT BOWEN, "HIGH TECH CERAMICS IN JAPAN - CURRENT AND FUTURE MARKETS" AMERICAN CERAMIC SOCIETY BULLETIN, MAY 1983

Production figures on IBM are not available because of the company's vertical integration. The world market for AC packaging, expected to experience the most growth in the electronic AC capacitor and resistor markets, is currently evenly split by the U.S. and Japan worldwide. Japan has gained its advantage in AC electronic components by using a superior, large-scale manufacturing process which results in lower production costs. Currently, IBM is the only U.S. firm that is competitive in the development of AC electronic components.

Trends in world market shares in AC engineering products (cutting tools, wear parts, heat engine parts) have not been established yet because of the small amounts of commercial production that have occurred. Japan is currently the dominant world supplier of pure ceramic powders from which these AC products are made. When large-scale commercial production of AC engineering products begins (projected to be before 1995), competition will be based on quality and price. The quality of AC engineering products is judged by thermal properties, hardness, corrosion resistance, and predictability of catastrophic failure. These products give no indication of failure through deformation, but instead disintegrate into smaller pieces, as opposed to conventional materials, which show signs of wear.

Role of Technology in the Long-Term Strategic Outlook

The AC products industry is definitely in the sunrise stage of development, as shown by its predicted growth in Table 12-7. New proposed technologies for the industry can be separated into advanced ceramic electronic components and advanced ceramic engineering products. The theory behind these technologies is discussed in Section E.1. Applications of these new technologies to various industries are discussed here and shown in Table 12-10.

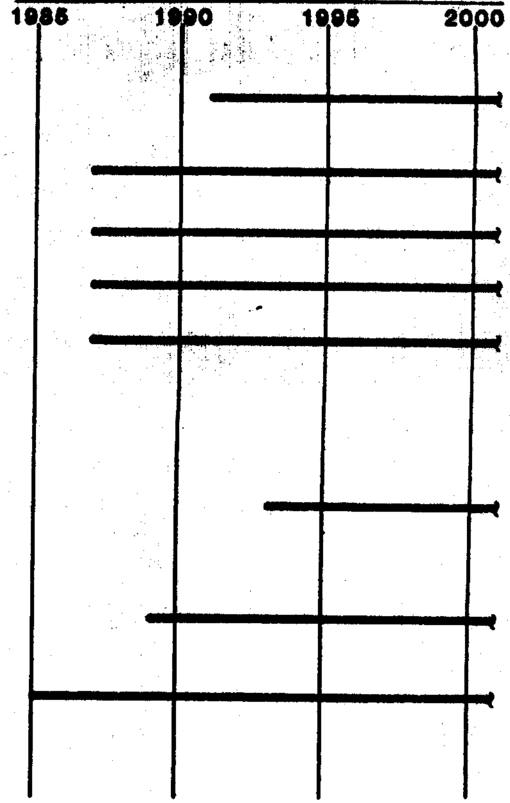
The electronic components and applications of advanced ceramic technology are as follows:

TABLE 12-10

APPLICATIONS OF ADVANCED CERAMIC TECHNOLOGY

APPLICATION	DESCRIPTION	PRINCIPAL IMPACT
ELECTRONIC APPLICATIONS		
● CAPACITORS	ADVANCED CERAMIC CAPACITORS MORE EFFICIENT CAPACITORS	INEXPENSIVE, SMALLER
● INTEGRATED CIRCUIT PACKAGING	FITTING IC CHIPS INTO CIRCUIT BOARDS	HIGHER PERFORMANCE AND RELIABILITY
● RESISTORS	ADVANCED CERAMIC THERMISTOR	IMPROVED CONTROL
● SENSORS	GAS AND TEMPERATURE SENSORS	BETTER CONTROL
● MAGNETIC COMPONENTS	PERMANENT MAGNETS, MEMORY UNITS, RADIO CIRCUIT ELEMENTS	SMALLER SIZE, LOWER COST
ENGINEERING PRODUCTS		
● HEAT ENGINE APPLICATIONS	IMPROVED PISTON ENGINES, CERAMIC ADIABATIC DIESEL ENGINE, CERAMIC GAS TURBINE ENGINE	INCREASED FUEL EFFICIENCY, MORE POWERFUL ENGINES
● CUTTING TOOLS	ADVANCED CERAMIC CUTTING EDGES EASIER USE OF ROBOTIC CUTTERS	HIGHER CUTTING SPEEDS
● WEAR PARTS	BEARINGS, SEALS, AND NOZZLES TECHNIQUES IN SOME INDUSTRIES	IMPROVE MANUFACTURING

APPROXIMATE ERA OF SIGNIFICANT DIFFUSION



SOURCE: U.S. DOC/IAD

- **Capacitors**--Multilayer ceramic capacitors are valued for their low capacitance levels, high dielectric constant, high resistivity, and low leakage. They are used in consumer electronic products, computers, telecommunications equipment, and scientific instruments. Cost, size, and speed of these capacitors will affect their future market. Major cost reduction can be achieved through the use of base metals (nickel, lead, and tin) in production as opposed to the noble metals (gold, platinum, palladium, and silver) currently being used. Noble metals currently account for 35% of the total cost of a multilayer ceramic capacitor. Reduction in capacitor size and an increase in capacitance value will increase the market share. Volumetric efficiency can be increased by increasing the dielectric constant, reducing the number of dielectric layers, or decreasing the thickness of dielectric layers. Use of new dielectric materials (lead, iron, tungsten, and lead iron niobate), better controlled processing parameters, increased automation, and improvements in ceramic powder purity will have to be used in order to meet this need. The speed of advanced ceramic capacitors (to be compatible with higher speeds of future integrated circuits) can be increased through the use of ceramic chip capacitors. These chip capacitors need to be standarized by size in order to gain wide market acceptance.

- **Integrated Circuit Packaging**--Advanced ceramic integrated circuit (IC) packaging is used to fit the semiconductor chip into larger circuit boards. A suitable operating environment within the computer or electronic device is produced by advanced ceramic IC packaging. Currently, the military is the primary user of ceramic IC packaging. The most promising ceramic IC packaging being developed is based on multilayer ceramic sub-

strates, consisting of layers of ceramic insulators alternating with conductor circuitry to form high-density wiring packages. As with ceramic capacitors, increased market share applications will depend on cost, size,and speed.

- **Resistors**--The use of ceramic thermistors should find increasing use as heat sensors in automobiles, to supply exhaust temperature data important to fuel efficiency, and in microwave and gas ovens.

- **Sensors**--The use of advanced ceramics in sensors is due to the semiconducting properties of ceramics, which allow them to transmit current only under certain conditions.

- **Magnetic Components**--AC materials with magnetic properties are used in permanent magnets, memory units, and circuit elements. They are derived from iron oxides combined with one or more metals (nickel, manganese, and zinc).

Advanced ceramic technology includes the following engineering applications:

- **Heat Engine Applications**--Advanced ceramics in heat engines will probably be used first in standard vehicular piston engines as components in cylinders, pistons, and turbochargers because major changes in production lines and engine technology will not be required for these applications. The major reason for using ceramic engines is their increased system performance, improved wear capability and lower weight. Critical flaws will also be easier to control. Turbocharger rotors are the most significant near-term item of an advanced ceramic component substitution. Ceramic

rotors are made from sintered silicon carbide. Research in ceramic turbocharger rotors is being conducted with private money, as opposed to most other heat engine applications which are government funded. Near-term ceramics substitution of other piston engine components include pistons and piston rings, cylinder liners and heads, valve lifters, and combustion chambers. Total ceramic piston engines are unlikely because they do not offer substantial gains in fuel economy or power production to warrant mass production. However, there are new vehicular engine designs which do offer significant gains in fuel economy and power production. These include the adiabatic diesel engine, which is made possible through the use of advanced ceramics. As compared to the conventional diesel engine, energy loss can be reduced by 50%, fuel consumption by 25%, and power can be increased significantly in the adiabatic diesel engine. These engines use thermal energy, normally lost to the coolant and exhaust systems, to make power through the use of turbomachinery. Use of a ceramic combustion chamber, (operating at high temperatures and reducing heat loss) with a turbocompound system, recovers the heat energy of the exhaust gases and transfers them to the crankshaft. Improved fuel economy and greater engine reliability is the result. The U.S. Army Tank Automotive Research and Development Command has been doing research in this area since 1976. Use in military and civilian heavy-duty trucks will come before use in automobiles.

Gas turbine engine use in vehicles became feasible in the 1960s with the development of advanced ceramic materials. Previously, the expense of the superalloys and their inability to withstand the high-operating temperatures prevented this development. AC gas tur-

bine engines alleviate the problem of expensive alloys, provide high temperature capabilities, and reduce wear on engine parts. Advantages of the turbine engine include improved fuel economy, lower engine weight, reduced maintenance, improved performance, and less pollutants. Currently the Department of Defense Advanced Research Projects Agency (DARPA) funds four R&D programs dealing with AC turbine engines. Stationary AC gas turbine engines are also being developed. The use of these engines in aircraft will be the last to be implemented, because of the high-performance needed and high-risk involved.

- **Cutting Tools**--Recent advances in AC materials and processing have made them competitive with high-speed steel and carbide cutting tools. Hardness, chemical stability, and heat resistance are all characteristics which give AC cutting tools an advantage. Ceramic materials are superior for cutting highly abrasive materials due to their resistance to wear, and are more effective for cutting at high speeds due to their resistance to heat. Resistance to thermal shock is one area where AC cutting tools are lacking because of their brittleness. Cutting tool use is currently very limited as compared to the potential market. Technological advances in the area of brittleness and thermal shock resistance (as compared to carbide machine tools) are needed before cutting tools can claim a substantial market piece. Silicon nitrate-based materials are considered to have a much greater potential than aluminum oxide ceramics, which have been available for 30 years. Alloying ceramic material with zirconia or titanium is being tried to improve fracture toughness. Unmanned machining (robotics) favors AC cutting tools because of the stiffness and long-life of the ceramic inserts.

- **Wear Part Applications**--Ball and roller bearings for high-performance applications made of AC materials (silicon nitride in particular) are now finding limited use in industrial machinery, for corrosive oil, gas, and chemical processing, and are being researched for use in automobile and aircraft engines. Improved processing methods have allowed densification of silicon carbide and silicon nitride, which has increased their tolerance to point or stress loading. The light weight, heat resistance, and wear resistance of ceramic bearings are major advantages over conventional (tungsten/steel) bearings. Their light weight makes the centrifugal load lower, thereby improving fatigue life and high-speed performance. Conventional tool steel (the highest temperature resistant material now in use) softens excessively after being exposed to high temperatures for long periods of time. Higher temperature resistant bearings (i.e., advanced ceramic bearings) will be necessary for future high-speed industrial machinery. Advanced ceramic pump seals are used in sand slurries, chemical processing, and oil and gas recovery. Currently they are the most widely used AC product in the wear parts category. The same properties that make AC products useful in other applications (hardness, low friction, high resistance to corrosion, high temperature capability) make them useful in pump seals. Temperature characteristics of advanced ceramics have made them perfect for this application, because of the need to dissipate heat at the surface of the seal. Stability of shape when heated quickly (dimensional stability) is also a critical feature of advanced ceramics. Sandblast nozzles are now being made of advanced ceramics due to the need for nozzles with high wear capabilities and abrasion resistance.

Table 12-11 lists the strategic materials that advanced ceramics could replace. Clearly, advanced ceramics will be a key to the future technological development of many industries.

Conclusion

The advanced ceramic industry is clearly experiencing rapid growth. Advances in AC technology are continuing in the areas of ceramic powder production, integrated circuit packaging, capacitors, cutting tools, wear parts, engine design, and other advanced ceramics products.

Industry shipment of AC products are expected to increase nearly ten fold in the next 20 years. AC products could replace the following strategic materials: tungsten, cobalt, nickel, chromium, molybdenum, manganese, titanium, platinum and palladium, columbium, and tantalum.

Currently, the U.S. and Japan are virtually equal with regards to technology in the field. If current conditions remain unchanged, U.S. will fall behind Japan in AC technology. According to the U.S. Department of Commerce, there are two categories of technology push and market pull. The technology push option involves:

- Federal R&D expenditures increased for advanced engineering ceramics. The money should be directed at solving the AC problem of catastrophic failure and at finding cost-effective manufacturing techniques.

- Provide an improved technology transfer function of AC technology from military and space applications to the private sector.

- Increase private R&D on AC technology through federal incentives such as tax incentives, matching funds, and low-interest loans.

TABLE 12-11

POSSIBLE ADVANCED CERAMICS SUBSTITUTION FOR STRATEGIC MATERIALS

MATERIAL	SYMBOL	APPLICATION WHERE CERAMICS MAY REPLACE THE MATERIAL	TECHNOLOGICAL BARRIERS FOR CERAMICS
TUNGSTEN	W	WEAR PARTS (LINERS, PADS, NOZZLES, BEARINGS, GATES, SLIDES, VALVES, SEALS).	DEMONSTRATION, SCALE UP, COST
COBALT	Co	DIESEL COMBUSTION PARTS	DEMONSTRATION, COST
		TURBOCHARGER ROTORS	N/A
		HEAT RECOVERY SYSTEMS	N/A
NICKEL	Ni	DIESEL COMBUSTION PARTS	DEMONSTRATION, PROPERTIES; MAINTENANCE OF CURRENT CREEP AND OXIDATION LEVELS, COST
		TURBOCHARGER ROTORS	N/A
		HEAT RECOVERY SYSTEMS	FABRICATION AND PERFORMANCE INNOVATIONS, DEMONSTRATION, COST
		CHEMICAL WARE (ANTI-CORROSION PIPING, VALVES, SEALS, ETC., GASIFIER COMPONENTS, COATINGS)	N/A
CHROMIUM	Cr	HEAT ENGINES	DEMONSTRATION, PROPERTIES, COST
		CHEMICAL WARE	N/A
		HEAT EXCHANGERS	FABRICATION, PERFORMANCE, DEMONSTRATION, COST
MOLYBDENUM	Mo	HEAT RECOVERY SYSTEMS	N/A
MANGANESE	Mn	HEAT ENGINES	DEMONSTRATION, PROPERTIES, COST
TITANIUM	Ti	WEAR PARTS	DEMONSTRATION, SCALE-UP, COST
		CUTTING TOOLS AND ABRASIVES	ACHIEVE HARDNESS, NEW COMPOSITES
		HEAT APPLICATIONS	N/A
PLATINUM AND PALLADIUM	Pt,Pd	CHEMICAL WARE	N/A
BERYLLIUM	Be	STRUCTURAL MEMBERS (FIBER REINFORCED SPARS; TILES; CASTINGS)	INNOVATION IN COMPOSITES, ORGANO-CERAMICS TECHNOLOGY DEVELOPMENT
COLUMBIUM (NIOBIUM)	Nb	HIGH-TEMPERATURE APPLICATION	FABRICATION, PERFORMANCE, DEMONSTRATION
TANTALUM	Ta	HIGH-TEMPERATURE APPLICATION	COSTS, HARDNESS POTENTIAL
		WEAR PARTS	N/A

N/A - NOT AVAILABLE.

SOURCE: L.R. JOHNSON, ET AL., "A STRUCTURAL CERAMIC RESEARCH PROGRAM: A PRELIMINARY ECONOMIC ANALYSIS," ARGONNE NATIONAL LABORATORY, MARCH 1983

- Improve the capacity of the U.S. to transfer foreign scientific advances in the AC field. This is one particular area where Japan is much better equipped.

- Stimulate universities and colleges to train advanced ceramics engineers by offering them federal funds for their programs.

The market pull option includes:

- To purchase federal items on the basis of their content of advanced ceramic products. This could include military items, automobiles, and office computing equipment.

- The Bureau of Standards must set reliability standards in AC products to insure quality.

- To provide AC producers with liability insurance due to the problem of AC catastrophic failure.

The primary need for advanced ceramic research, however, is in the areas of solving the catastrophic failure problem and in finding a cost-effective method of production.

B.13 RUBBER AND MISCELLANEOUS PLASTICS PRODUCTS (SIC 30)

TABLE OF CONTENTS

SOURCES: U.S. DOC/BOC:

Statistical Abstract of the U.S. 1982-83
Census of Manufacturers, 1977
Annual Survey of Manufacturers, 1981

EOP/DMB:

Standard Industrial Classification Manual, 1972

U.S. DOC/BIE:

Industrial Outlook, 1984

U.S. DOL/BLS:

Value-Line Investment Survey, 1984
Moody's Handbook, 1984

LIST OF TABLES

B.13 "RUBBER AND MISCELLANEOUS PLASTICS PRODUCTS" (SIC 30)

The rubber and miscellaneous plastics products subsector, SIC 30, whose value added accounted for 2.9% of the manufacturing sector's contribution to GDP in 1980, comprises the 14th largest manufacturing industry (in this study, the apparel and other textile products subsector, SIC 23, the 13th largest manufacturing industry will not be covered). The subsector is characterized by:

- A high degree of fragmentation. Out of a total of approximately 18,000 establishments, 13,000 employ less than 20 persons (1977).

- A low labor productivity of $17,988 per employee or $9.37 per employee hour (1980, 1972 $), ranking this subsector fourteenth among the nation's 20 manufacturing subsectors. A compound annual labor productivity growth rate average of -0.6%/year from 1972 to 1980 ranks this subsector last. The labor productivity for the comparable Japanese subsector was $11,508 per employee year or $5.99 per employee hour (1980, 1972 $), ranking this subsector eleventh among Japan's 20 manufacturing subsectors. The compound annual labor productivity growth rate for the Japanese subsector averaged 4.4%/year from 1972 to 1980, ranking this subsector sixteenth.

- An average capital investment base relative to other subsectors within the manufacturing sector. Capital investment amounted to $15,962 in total assets per worker, ranking eighth in terms of (depreciated) fixed assets (1980, 1972 $). New yearly capital expenditures were $1,648 per employee (1980, 1972 $), ranking eleventh in the manufacturing sector. Total capital productivity, measured as dollars of added value output per dollar investment, was 0.82 (1981).

- An average R&D program. For the subsector as a whole, R&D expenditures amounted to $0.4 billion (1980, 1972 $), ranking this subsector eighth among the 20 manufacturing subsectors. R&D expenditures were equivalent to 2.9% of the value added by the subsector in 1980.

Table 13-1 shows the major products of each subdivision of the rubber and miscellaneous plastics products industry, with their share of the subsector's contribution to GDP in 1980 ranked in descending order. Table 13-2 summarizes the principal economic measures of these subdivisions.

One subdivision--miscellaneous plastics products (SIC 307 or 3079) which consists of manufactured plastic products of all types with the exception of plastic footwear and plastic hose/belting--accounted for 64% of the subsector's output in 1980. Because this subdivision considerably dominates the other subdivisions within this industry, it has been selected for analysis in order to assess long term technology needs.

B.13.1 MISCELLANEOUS PLASTICS PRODUCTS (SIC 307)

The total plastics industry produced $54 billion in shipments in 1983. The miscellaneous plastics products subdivision accounted for $37 billion of shipments or 68%; the remaining 32%, classified as plastics materials and resins (SIC 2821), constitutes captive production or the self-manufacture of plastic products to be consumed within other major industry groups. Examples of the latter are the automotive industry, food packaging materials, and toy manufacturers. Miscellaneous plastics products are associated with all other plastic products industries (with the exception of plastic footwear and plastic hose/belting).

TABLE 13-1

CLASSIFICATION OF MAJOR PRODUCTS OF THE RUBBER AND MISCELLANEOUS PLASTICS PRODUCTS INDUSTRY (SIC 30) AND CONTRIBUTION TO SUBSECTOR IN 1980

SIC CODE	SUBDIVISION DESIGNATION AND TYPICAL PRODUCTS	% CONTRIBUTION
307	MISCELLANEOUS PLASTICS PRODUCTS PLASTIC PRODUCTS OF ALL TYPES EXCEPT PLASTIC FOOTWEAR AND PLASTIC HOSE/BELTING	64.4
301	TIRES AND INNER TUBES RUBBER INNER TUBES, TIRES, AND TIRE REPAIR MATERIALS	18.0
306	OTHER FABRICATED RUBBER PRODUCTS INDUSTRIAL AND MECHANICAL RUBBER GOODS, RUBBERIZED FABRICS AND VULCANIZED RUBBER CLOTHING	12.0
304	RUBBER AND PLASTICS HOSE AND BELTING AUTOMOBILE, GARDEN, VACUUM AND OTHER RUBBER AND PLASTIC HOSES AND BELTS	4.1
302	RUBBER AND PLASTICS FOOTWEAR RUBBER AND PLASTIC BOOTS, SHOES, AND OTHER FOOTWEAR	1.4
303	RECLAIMED RUBBER RECLAIMED RUBBER PRODUCTS OF ALL TYPES	0.1
30	ALL RUBBER AND PLASTIC PRODUCTS	100.0

SOURCES: U.S. DOC/BOC: STATISTICAL ABSTRACT OF THE U.S. 1982-3
EOP/OMB: STANDARD INDUSTRIAL CLASSIFICATION MANUAL, 1972

TABLE 13-2

SUBDIVISIONS AND CHARACTERIZATION OF RUBBER AND MISCELLANEOUS PLASTICS INDUSTRY (SIC 30) DURING 1980, IN 1972 DOLLARS

SUBDIVISION	PERCENTAGE CONTRIBUTION	NUMBER OF EMPLOYEES (1,000)	NUMBER OF ESTABLISHMENTS[a]			GROSS VALUE OF FIXED ASSETS/ ($/EMPLOYEE)	NEW CAPITAL EXPENDITURES ($/EMPLOYEE)	LABOR PRODUCTIVITY ($/EMPLOYEE)
			TOTAL	LESS THAN 20 EMPLOYEES	100 OR MORE EMPLOYEES			
ALL RUBBER & MISC. PLASTICS (30)	100	703.2	11,943	6,649	1,554	15,967	1,648	17,988
TIRES AND INNER TUBES (301)	18.0	87.2	200	74	94	28,122	2,126	26,196
RUBBER, PLASTICS FOOTWEAR (302)	1.4	18.0	84	34	34	4,132	389	9,581
RECLAIMED RUBBER (303)	0.1	0.6	21	12	3	38,112	747	22,979
RUBBER AND PLASTICS HOSE, BELTING (304)	4.1	32.4	146	43	63	22,286	2,064	15,856
FABRICATED RUBBER PRODUCTS (306)	12.0	94.9	1,280	659	237	11,354	950	16,006
MISC. PLASTICS PRODUCTS (307)	64.4	470.1	10,212	5,827	1,123	14,626	1,722	17,328

[a] 1977

SOURCE: U.S. DOB/BOC: CENSUS OF MANUFACTURES, 1977
U.S. DOC/BOC: ANNUAL SURVEY OF MANUFACTURES, 1981

Business and structural profiles of the miscellaneous and plastic products subdivision are presented in Tables 13-3 and 13-4, respectively. Table 13-3 shows that industry shipments expressed in constant 1972 dollars, have increased 55% in eleven years, from $10.7 billion in 1972 to $16.6 billion in 1983. Employment rose steadily up to 1979, after which it stabilized at a slightly lower level. Labor productivity, i.e., output per employee hour, rose from 1972 to 1977, and has stabilized at that level.

Table 13-4 shows that the miscellaneous plastics products industry is highly fragmented; 75% of its establishments employ less than 20 persons. A typical manufacturer in this industry earned a net income of 3% after taxes in 1981 on sales of about $5 million. The typical plastics fabricator is a small, independent business with a potential for modular operations and incremental expansion. Its finished product is dominated primarily by the cost of input materials (49%), and secondarily by manufacturing and other labor (21%) costs. In 1979 and 1983, the value of exports in this industry was nearly twice the size of imports.

The dominant constraint in the miscellaneous plastics products industry is cost. Because plastic is a petrochemical-based product, the cost of plastic is dependent on the cost of oil.

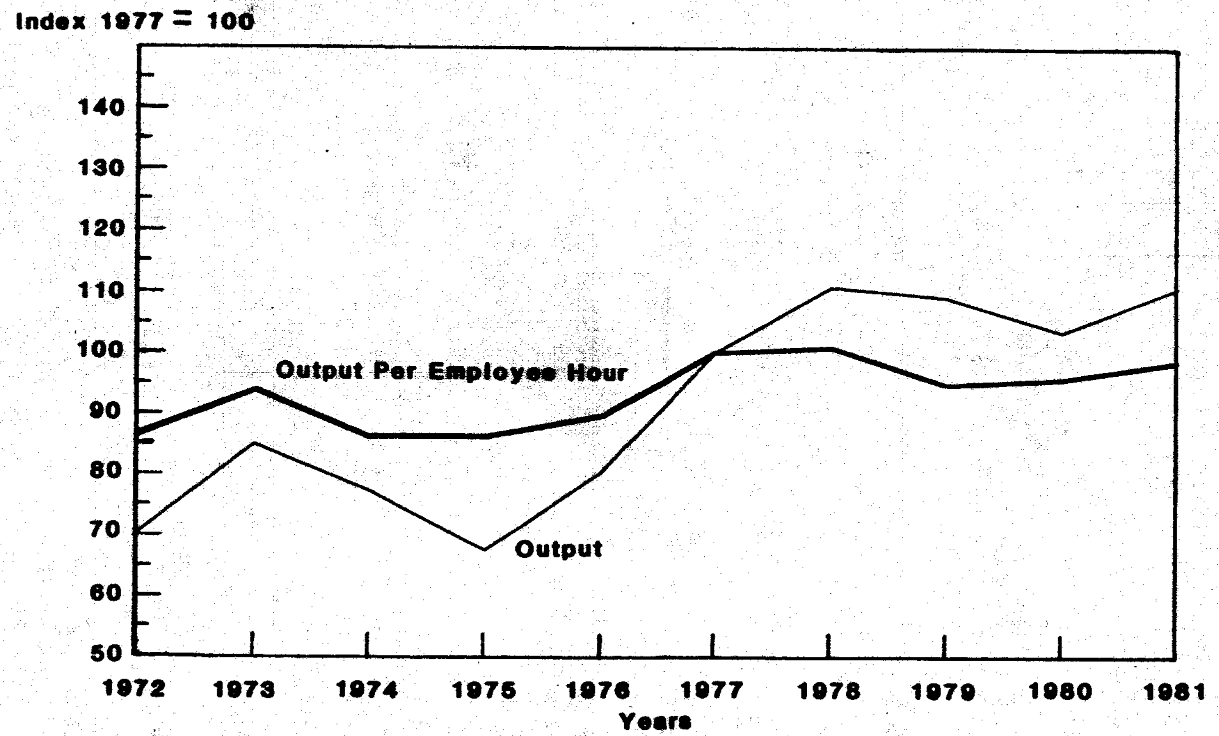
Key Growth Influences in the Miscellaneous Plastic Products Industry

The use of fabricated plastic parts has undergone a significant change in focus over the last five years. Whereas the early growth of the industry was driven by the low cost substitution of plastic parts for natural materials, advances in polymer and processing technologies in the 1980s have resulted in the production of plastic parts with superior performance to natural

TABLE 13-3

BUSINESS PROFILE OF THE
MISCELLANEOUS PLASTICS PRODUCTS INDUSTRY (SIC 307)

SHIPMENTS (BILLION $)	1972	1977	1979	1981	1983	1984 EST
CURRENT $	10.7	23.7	29.1	34.1	37.0	--
1972 $	10.7	14.6	15.6	15.7	16.6	17.9
TOTAL EMPLOYMENT (THOUSANDS)	346.9	453.7	487.7	469.5	452.2	465.0



Source: BLS Data

PLANT CAPACITY UTILIZATION, 1982 %	64.0
PRETAX PROFIT, 1981, %	4.2
RETURN ON EQUITY, 1983, %	4.7
VALUE OF PLANT, 1976, CURRENT $, BILLION	7.3

	1977	1981
NEW CAPITAL EXPENDITURES, CURRENT $, BILLION	1.2	1.6

SOURCES: U.S. DOC/BIE: 1984 U.S. INDUSTRIAL OUTLOOK
U.S. DOC/BOC: CENSUS OF MANUFACTURES, 1977
U.S. DOL/BLS
VALUE-LINE INVESTMENT SURVEY, 1984

TABLE 13-4

STRUCTURAL PROFILE OF THE
MISCELLANEOUS PLASTICS PRODUCTS INDUSTRY (SIC 307)

ESTABLISHMENTS (1977)

(CATEGORIZED BY NO. OF EMPLOYEES)

SMALL (< 20)	5,827
INTERMEDIATE (20 - 1000)	4,368
LARGE (> 1000)	17
TOTAL (8,824 COMPANIES)	10,212

REPRESENTATIVE FIRMS (1983)

NAME	TOTAL REVENUES (MILLION $)
RUBBERMAID, INC.	436.4
WEST CO., INC	190.4
SEALED AIR CORP.	124.5

PRODUCTION COST	MFG. LABOR	OTHER LABOR	MATERIALS	ENERGY	CAPITAL
DISTRIBUTION, 1977	14%	7%	49%	2%	28%

R&D EXPENDITURES

CURRENT $, MILLION, 1981	500

INTERNATIONAL TRADE	1972	1979	1983
VALUE OF EXPORTS, CURRENT $, BILLION	0.38	1.5	1.9
VALUE OF IMPORTS, CURRENT $, BILLION	0.25	0.8	1.0

SOURCES: U.S. DOC/BIE: 1984 U.S. INDUSTRIAL OUTLOOK
U.S. DOC/BOC: CENSUS OF MANUFACTURES, 1977
MOODY'S HANDBOOK, 1984

materials (e.g., ceramics, metals, and wood). At the same time, the average cost of high performance resins has continued to drop through the use of alloying or blending with lower-cost commodity thermoplastics. The result, in many cases, is a lower-cost, higher-performing plastic part.

A second major growth influence in the plastics products industry is the key role that plastics fabrication plays in the rapidly-growing electronics industry, in areas as diverse as printed circuit boards and business machine housings.

Technology Trends In The Miscellaneous Plastics Products Industry

Most technological advances which impact the plastic products industry are developed outside the industry. For example, the packaging industry has been a leading proponent of the so-called "plastic can", a product being developed to replace the metal can in many food applications. The actual development process has involved packaging companies, plastic resin companies, equipment manufacturers and, of course, fabricators. In point of fact, the packaging company, equipment company, and resin manufacturer work out the details and the fabricator will "take orders" for producing the final product. Another second source of technical development is derived directly from equipment manufacturers, a group that has a vested interest in developing new and different equipment in order to obsolete "old" machines and maintain industry shipments.

This outside influence is typical of the plastic products industry, in which smaller fabrication companies do not have the budget or interest to take on any but the most elementary research and development projects. They prefer to leave this work to the larger resin and/or food packaging companies. In all probability, any significant product or process developments will come from these integrated companies.

Plastic fabrication processes which show the highest level of future activity include:

- Resin transfer molding
- Twin screw extrusion and compounding
- Reaction injection molding (RIM)
- Sheet molding compound (SMC) and injection molding of bulk molding compound
- Pultrusion
- Thermoforming
- Sheet and film co-extrusion and lamination, and
- Injection blow-molding and co-extrusion blow-molding

All of these technologies are being pursued today and many are already part of viable commercial operations. Future development efforts are likely to be focused on such areas as cold stampable polymers, high-strength structural composites, super-high temperature polymer processing, flame-retardant plastic products, biodegradable plastic parts, and so on. However, it is unlikely that any of these development efforts will be supported by the fabrication industry itself. These projects will be undertaken by resin manufacturers, end users, or outside third parties.

<u>Long-Term Technological Assessment of the Miscellaneous Plastics Products Industry</u>

Over the next five to 15 years, the miscellaneous plastics products industry should experience a solid, but cyclical growth rate as the redefined role of substitution and the growth of the electronics industry drive plastic products demand. In-house fabrication together with selected custom fabricators will support most of these technology developments. However, these developments will be more likely driven by the end user rather than the fabrication process itself. In the longer term, as the needs of end users become more sophisticated and product and

process technology becomes more proprietary, the role of the independent fabricator in areas outside of commodity applications could be decreased.

The technological challenge in this industry will continue to be the development and fabrication of synthetic materials with superior performance and light weight--so called high performance structural composites. Superior performance will depend on two factors: 1) the material used, a function of the up-stream industries; and 2) the method of "putting materials together." Current research in these areas is driven by the automotive and air transportation industries. This research will incorporate developments from all segments of the chemical, polymer and fabricated products industries and will have wide-ranging applications. For example, in the long term, synthetic material could go a long way towards replacing conventional building materials.

Generally, the long-term technological challenge will be to derive the same performance from synthetic materials--cubic inch for cubic inch--that is currently possible from conventional materials such as steel and wood. Pound for pound, synthetics are already superior to natural materials in many end uses, and, the inventory of useable synthetic materials is quite large: 50 unique polymers, a dozen or so fibers, and an almost unlimited number of fillers and additives. It is most likely, therefore, that future breakthroughs in the development of structural synthetic materials will derive from selecting the right materials among a multitude of choices and fabricating them in such a way as to achieve a unique performance.

Assuming that both the materials and a structure are available, key technologies will also depend upon the designing of machines to perform a particular task. An example which received considerable publicity was the design and fabrication of a structural skeleton for a space station. Work is currently being performed on an epoxy-impregnated carbon-fiber ribbon, which can

be fed into a fabricating machine and converted into a structural "beam". This lightweight, yet strong material, and the process associated with its conversion to a useful product, could greatly reduce the cost of building in space.

In addition, new technologies need to be developed in the adhesives industry. As synthetic building materials emerge, new ways must be developed to hold the pieces together--quite likely mechanical fasteners will give way to chemical fasteners or adhesives.

Many of these technology issues have already surfaced in the aerospace and automotive industry as engineers have sought improved fuel economy through weight reduction. For example, the relatively simple task of aligning automotive body parts for welding became nearly impossible when the industry started using plastic with pre-drilled holes--the parts would never line up exactly with the holes. A potential solution to this problem is to use adhesives. However, there is clearly a long way to go before we can efficiently produce these products with synthetic materials.

In the future, it will become more difficult to distinguish between rubber and plastic products. Alloys and blends of elastomers and plastic resins are common today and will increase over time. Plastic resins provide stiffness for rubber products and elastomers provide impact resistance and flexibility for plastic products. Both are made from synthetic resins which are derived from many of the same basic molecules. Thus, the final part of this challenge will be to look beyond conventional industry boundaries in search of all kinds of materials which can be combined with rubber and plastic to create new structural composites.

Conclusion

The miscellaneous plastics products industry is one of the fastest growing industries in the U.S., although at present it is the smallest (in-terms of value-added contribution to GDP) industry reviewed in this report. In the future, the industry is expected to continue to grow faster than the U.S. economy in general as plastics are combined with textiles, fiberglass, rubber, and carbon fibers to produce composites to replace currently-used conventional materials. The new composite materials will be found in a wide range of products ranging from aircraft and automobiles to buildings.

The miscellaneous plastics products industry has an average R&D program but augments developments that arise with research advances developed by other industries.

The needs of the industry can be categorized into two areas:

- Development of synthetic materials to replace wood and metal as structural building materials, and to replace or be blended more with rubber. Currently, this development is dependent upon research results from the chemical, polymer, and fabricated products industries.

- New technologies are needed to develop chemical adhesives to replace currently used mechanical fasteners.

- Improve the capacity of the U.S. to transfer foreign scientific advances in the AC field. This is one particular area where Japan is much better equipped.

- Stimulate universities and colleges to train advanced ceramics engineers by offering them federal funds for their programs.

The market pull option includes:

- To purchase federal items on the basis of their content of advanced ceramic products. This could include military items, automobiles, and office computing equipment.

- The Bureau of Standards must set reliability standards in AC products to insure quality.

- To provide AC producers with liability insurance due to the problem of AC catastrophic failure.

The primary need for advanced ceramic research, however, is in the areas of solving the catastrophic failure problem and in finding a cost-effective method of production.

B.13 RUBBER AND MISCELLANEOUS PLASTICS PRODUCTS (SIC 30)

TABLE OF CONTENTS

SOURCES: U.S. DOC/BOC:

Statistical Abstract of the U.S. 1982-83

Census of Manufacturers, 1977

Annual Survey of Manufacturers, 1981

EOP/DMB:

Standard Industrial Classification Manual, 1972

U.S. DOC/BIE:

Industrial Outlook, 1984

U.S. DOL/BLS:

Value-Line Investment Survey, 1984

Moody's Handbook, 1984

LIST OF TABLES

B.13 "RUBBER AND MISCELLANEOUS PLASTICS PRODUCTS" (SIC 30)

The rubber and miscellaneous plastics products subsector, SIC 30, whose value added accounted for 2.9% of the manufacturing sector's contribution to GDP in 1980, comprises the 14th largest manufacturing industry (in this study, the apparel and other textile products subsector, SIC 23, the 13th largest manufacturing industry will not be covered). The subsector is characterized by:

- A high degree of fragmentation. Out of a total of approximately 18,000 establishments, 13,000 employ less than 20 persons (1977).

- A low labor productivity of $17,988 per employee or $9.37 per employee hour (1980, 1972 $), ranking this subsector fourteenth among the nation's 20 manufacturing subsectors. A compound annual labor productivity growth rate average of -0.6%/year from 1972 to 1980 ranks this subsector last. The labor productivity for the comparable Japanese subsector was $11,508 per employee year or $5.99 per employee hour (1980, 1972 $), ranking this subsector eleventh among Japan's 20 manufacturing subsectors. The compound annual labor productivity growth rate for the Japanese subsector averaged 4.4%/year from 1972 to 1980, ranking this subsector sixteenth.

- An average capital investment base relative to other subsectors within the manufacturing sector. Capital investment amounted to $15,962 in total assets per worker, ranking eighth in terms of (depreciated) fixed assets (1980, 1972 $). New yearly capital expenditures were $1,648 per employee (1980, 1972 $), ranking eleventh in the manufacturing sector. Total capital productivity, measured as dollars of added value output per dollar investment, was 0.82 (1981).

- An average R&D program. For the subsector as a whole, R&D expenditures amounted to $0.4 billion (1980, 1972 $), ranking this subsector eighth among the 20 manufacturing subsectors. R&D expenditures were equivalent to 2.9% of the value added by the subsector in 1980.

Table 13-1 shows the major products of each subdivision of the rubber and miscellaneous plastics products industry, with their share of the subsector's contribution to GDP in 1980 ranked in descending order. Table 13-2 summarizes the principal economic measures of these subdivisions.

One subdivision--miscellaneous plastics products (SIC 307 or 3079) which consists of manufactured plastic products of all types with the exception of plastic footwear and plastic hose/belting--accounted for 64% of the subsector's output in 1980. Because this subdivision considerably dominates the other subdivisions within this industry, it has been selected for analysis in order to assess long term technology needs.

B.13.1 MISCELLANEOUS PLASTICS PRODUCTS (SIC 307)

The total plastics industry produced $54 billion in shipments in 1983. The miscellaneous plastics products subdivision accounted for $37 billion of shipments or 68%; the remaining 32%, classified as plastics materials and resins (SIC 2821), constitutes captive production or the self-manufacture of plastic products to be consumed within other major industry groups. Examples of the latter are the automotive industry, food packaging materials, and toy manufacturers. Miscellaneous plastics products are associated with all other plastic products industries (with the exception of plastic footwear and plastic hose/belting).

TABLE 13-1

CLASSIFICATION OF MAJOR PRODUCTS OF THE RUBBER AND MISCELLANEOUS PLASTICS PRODUCTS INDUSTRY (SIC 30) AND CONTRIBUTION TO SUBSECTOR IN 1980

SIC CODE	SUBDIVISION DESIGNATION AND TYPICAL PRODUCTS	% CONTRIBUTION
307	MISCELLANEOUS PLASTICS PRODUCTS PLASTIC PRODUCTS OF ALL TYPES EXCEPT PLASTIC FOOTWEAR AND PLASTIC HOSE/BELTING	64.4
301	TIRES AND INNER TUBES RUBBER INNER TUBES, TIRES, AND TIRE REPAIR MATERIALS	18.0
306	OTHER FABRICATED RUBBER PRODUCTS INDUSTRIAL AND MECHANICAL RUBBER GOODS, RUBBERIZED FABRICS AND VULCANIZED RUBBER CLOTHING	12.0
304	RUBBER AND PLASTICS HOSE AND BELTING AUTOMOBILE, GARDEN, VACUUM AND OTHER RUBBER AND PLASTIC HOSES AND BELTS	4.1
302	RUBBER AND PLASTICS FOOTWEAR RUBBER AND PLASTIC BOOTS, SHOES, AND OTHER FOOTWEAR	1.4
303	RECLAIMED RUBBER RECLAIMED RUBBER PRODUCTS OF ALL TYPES	0.1
30	ALL RUBBER AND PLASTIC PRODUCTS	100.0

SOURCES: U.S. DOC/BOC: STATISTICAL ABSTRACT OF THE U.S. 1982-3
EOP/OMB: STANDARD INDUSTRIAL CLASSIFICATION MANUAL, 1972

TABLE 13-2

SUBDIVISIONS AND CHARACTERIZATION OF RUBBER AND MISCELLANEOUS PLASTICS INDUSTRY (SIC 30) DURING 1980, IN 1972 DOLLARS

SUBDIVISION	PERCENTAGE CONTRIBUTION	NUMBER OF EMPLOYEES (1,000)	NUMBER OF ESTABLISHMENTS[a]			GROSS VALUE OF FIXED ASSETS/ ($/EMPLOYEE)	NEW CAPITAL EXPENDITURES ($/EMPLOYEE)	LABOR PRODUCTIVITY ($/EMPLOYEE)
			TOTAL	LESS THAN 20 EMPLOYEES	100 OR MORE EMPLOYEES			
ALL RUBBER & MISC. PLASTICS (30)	100	703.2	11,943	6,649	1,554	15,967	1,648	17,988
TIRES AND INNER TUBES (301)	18.0	87.2	200	74	94	28,122	2,126	26,196
RUBBER, PLASTICS FOOTWEAR (302)	1.4	18.0	84	34	34	4,132	389	9,581
RECLAIMED RUBBER (303)	0.1	0.6	21	12	3	38,112	747	22,979
RUBBER AND PLASTICS HOSE, BELTING (304)	4.1	32.4	146	43	63	22,286	2,064	15,856
FABRICATED RUBBER PRODUCTS (306)	12.0	94.9	1,280	659	237	11,354	950	16,006
MISC. PLASTICS PRODUCTS (307)	64.4	470.1	10,212	5,827	1,123	14,626	1,722	17,328

[a] 1977

SOURCE: U.S. DOB/BOC: CENSUS OF MANUFACTURES, 1977
U.S. DOC/BOC: ANNUAL SURVEY OF MANUFACTURES, 1981

Business and structural profiles of the miscellaneous and plastic products subdivision are presented in Tables 13-3 and 13-4, respectively. Table 13-3 shows that industry shipments expressed in constant 1972 dollars, have increased 55% in eleven years, from $10.7 billion in 1972 to $16.6 billion in 1983. Employment rose steadily up to 1979, after which it stabilized at a slightly lower level. Labor productivity, i.e., output per employee hour, rose from 1972 to 1977, and has stabilized at that level.

Table 13-4 shows that the miscellaneous plastics products industry is highly fragmented; 75% of its establishments employ less than 20 persons. A typical manufacturer in this industry earned a net income of 3% after taxes in 1981 on sales of about $5 million. The typical plastics fabricator is a small, independent business with a potential for modular operations and incremental expansion. Its finished product is dominated primarily by the cost of input materials (49%), and secondarily by manufacturing and other labor (21%) costs. In 1979 and 1983, the value of exports in this industry was nearly twice the size of imports.

The dominant constraint in the miscellaneous plastics products industry is cost. Because plastic is a petrochemical-based product, the cost of plastic is dependent on the cost of oil.

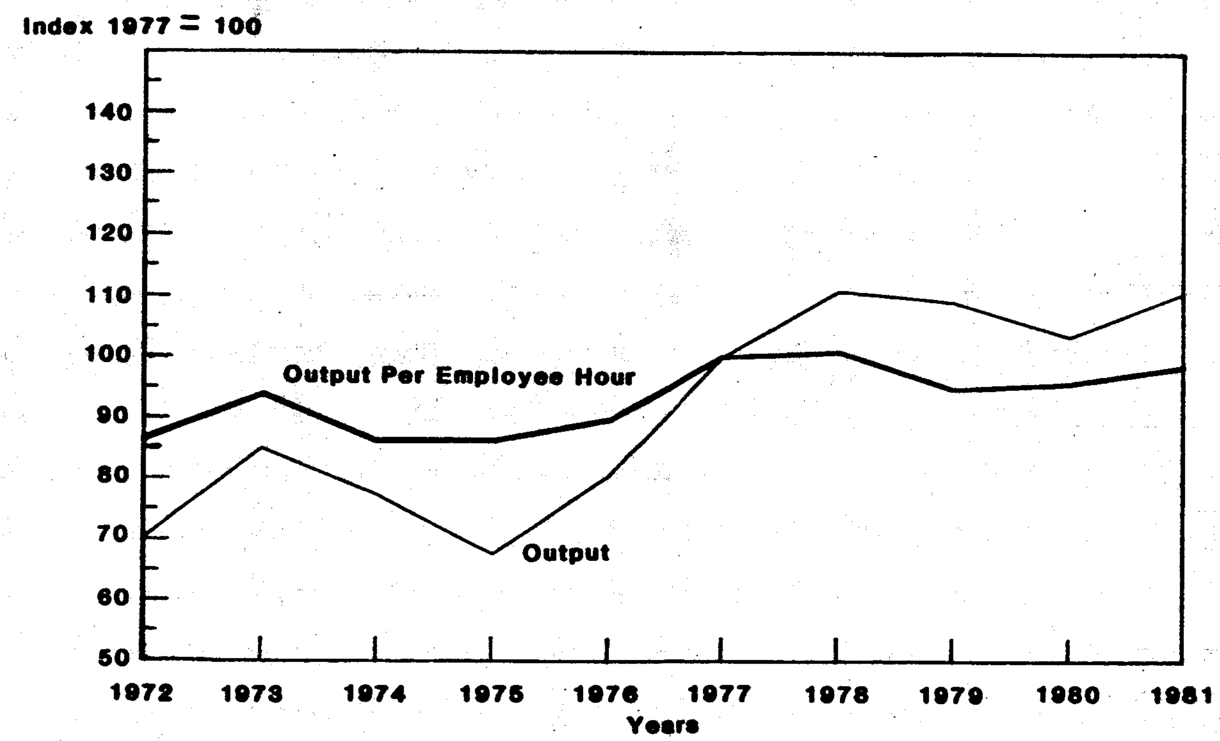
Key Growth Influences in the Miscellaneous Plastic Products Industry

The use of fabricated plastic parts has undergone a significant change in focus over the last five years. Whereas the early growth of the industry was driven by the low cost substitution of plastic parts for natural materials, advances in polymer and processing technologies in the 1980s have resulted in the production of plastic parts with superior performance to natural

TABLE 13-3

BUSINESS PROFILE OF THE
MISCELLANEOUS PLASTICS PRODUCTS INDUSTRY (SIC 307)

SHIPMENTS (BILLION $)	1972	1977	1979	1981	1983	1984 EST
CURRENT $	10.7	23.7	29.1	34.1	37.0	--
1972 $	10.7	14.6	15.6	15.7	16.6	17.9
TOTAL EMPLOYMENT (THOUSANDS)	346.9	453.7	487.7	469.5	452.2	465.0



Source: BLS Data

PLANT CAPACITY UTILIZATION, 1982 %	64.0
PRETAX PROFIT, 1981, %	4.2
RETURN ON EQUITY, 1983, %	4.7
VALUE OF PLANT, 1976, CURRENT $, BILLION	7.3

	1977	1981
NEW CAPITAL EXPENDITURES, CURRENT $, BILLION	1.2	1.6

SOURCES: U.S. DOC/BIE: 1984 U.S. INDUSTRIAL OUTLOOK
U.S. DOC/BOC: CENSUS OF MANUFACTURES, 1977
U.S. DOL/BLS
VALUE-LINE INVESTMENT SURVEY, 1984

TABLE 13-4

STRUCTURAL PROFILE OF THE
MISCELLANEOUS PLASTICS PRODUCTS INDUSTRY (SIC 307)

ESTABLISHMENTS (1977)

(CATEGORIZED BY NO. OF EMPLOYEES)

SMALL (< 20)	5,827
INTERMEDIATE (20 - 1000)	4,368
LARGE (> 1000)	17
TOTAL (8,824 COMPANIES)	10,212

REPRESENTATIVE FIRMS (1983)

NAME	TOTAL REVENUES (MILLION $)
RUBBERMAID, INC.	436.4
WEST CO., INC	190.4
SEALED AIR CORP.	124.5

PRODUCTION COST	MFG. LABOR	OTHER LABOR	MATERIALS	ENERGY	CAPITAL
DISTRIBUTION, 1977	14%	7%	49%	2%	28%

R&D EXPENDITURES

CURRENT $, MILLION, 1981	500

INTERNATIONAL TRADE	1972	1979	1983
VALUE OF EXPORTS, CURRENT $, BILLION	0.38	1.5	1.9
VALUE OF IMPORTS, CURRENT $, BILLION	0.25	0.8	1.0

SOURCES: U.S. DOC/BIE: 1984 U.S. INDUSTRIAL OUTLOOK
U.S. DOC/BOC: CENSUS OF MANUFACTURES, 1977
MOODY'S HANDBOOK, 1984

materials (e.g., ceramics, metals, and wood). At the same time, the average cost of high performance resins has continued to drop through the use of alloying or blending with lower-cost commodity thermoplastics. The result, in many cases, is a lower-cost, higher-performing plastic part.

A second major growth influence in the plastics products industry is the key role that plastics fabrication plays in the rapidly-growing electronics industry, in areas as diverse as printed circuit boards and business machine housings.

Technology Trends In The Miscellaneous Plastics Products Industry

Most technological advances which impact the plastic products industry are developed outside the industry. For example, the packaging industry has been a leading proponent of the so-called "plastic can", a product being developed to replace the metal can in many food applications. The actual development process has involved packaging companies, plastic resin companies, equipment manufacturers and, of course, fabricators. In point of fact, the packaging company, equipment company, and resin manufacturer work out the details and the fabricator will "take orders" for producing the final product. Another second source of technical development is derived directly from equipment manufacturers, a group that has a vested interest in developing new and different equipment in order to obsolete "old" machines and maintain industry shipments.

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Assuming that both the materials and a structure are available, key technologies will also depend upon the designing of machines to perform a particular task. An example which received considerable publicity was the design and fabrication of a structural skeleton for a space station. Work is currently being performed on an epoxy-impregnated carbon-fiber ribbon, which can

be fed into a fabricating machine and converted into a structural "beam". This lightweight, yet strong material, and the process associated with its conversion to a useful product, could greatly reduce the cost of building in space.

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- New technologies are needed to develop chemical adhesives to replace currently used mechanical fasteners.